

JOURNAL OF  
**THE ROYAL SOCIETY**  
OF  
**WESTERN AUSTRALIA**

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# The Royal Society of Western Australia, Inc.

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## ANNUAL REPORT OF THE COUNCIL FOR THE YEAR ENDING 30th JUNE, 1972

### Membership

Fourteen ordinary members were admitted into the Society during the year. In the same period six people resigned and three with whom contact had been lost for some years, were removed from membership.

Three deaths have been reported. Professor Teakle was elected as an Honorary Member at the 1971 Annual General Meeting. The membership now stands at Ordinary Members 257, Honorary Members 6, Honorary Associate Members 2, Total 265.

### Council

Ten ordinary and one special meeting of the Council were held during the year. Attendances were as follows: Dr. G. Storr (President) 10, Prof. R. M. Berndt 2, Prof. G. A. Bottomley 7, Dr. D. Bradshaw 4, Mr. S. J. Curry 9, Prof. B. J. Grieve 4, Mrs. S. J. Hallam 3, (Mr R. N. Hilton 1), Mr. D. Lowry 7, Dr. A. J. McComb 10, Dr. D. Merrilees 9, Mr. L. Peet 8, Dr. P. E. Playford 5, Dr. P. G. Quilty 10, Dr. B. P. Springett 1, Dr. J. A. Springett 3, Dr. A. Trendall 9, Mr. P. Wilson 9.

Prof. Berndt was overseas during the first half of 1972 and was granted leave of absence for this period.

Mr. R. N. Hilton, who was due to take sabbatical leave from December 1971, served as acting Treasurer until November of that year after which the position of Treasurer was filled by Mr. D. Lowry.

Dr. B. P. Springett resigned from the Council in February 1972, owing to other commitments. The vacancies on Council caused by his resignation and the acceptance by Mr. Lowry of the Honorary Treasurership, were filled in March by Mrs. S. J. Hallam and by Dr. J. A. Springett.

### Meetings

Nine ordinary General Meetings were held during the year. The title of the lectures or films at these meetings were as follows:

#### August

"Archaeologists as Ecologists" by Mrs. S. Hallam.

#### September

"Rock Lobsters in the Pacific Islands" by Dr. R. W. George.

#### October

"The Corridor Plan for the region of Perth" by Dr. D. Carr.

#### November

"Current issues in conservation—The role of the University" by Dr. W. D. L. Ride.

#### December

Film evening.

#### March

"Sea floor spreading and its relationship to Continental Drift" by Dr. Peter Verrall.

#### April

"Comments on the Corridor Plan for the region of Perth and an alternative" by Cr. Paul Ritter.

#### May

"Environment 2000—Plan and campaign on the use of Garden Island" by Mr. C. V. Malcolm and Professor H. Marshall.

#### June

"Excavation work on the 'Gilt Dragon'" by Mr. Jeremy Green.

At the Annual General Meeting which was held on July 26, 1971 in the W.A. Art Gallery, Professor B. J. Grieve gave a lecture entitled 'Survey of botanical progress in Western Australia'. The incoming President, Dr. G. M. Storr, was later installed in absentia by Lieutenant Governor, Sir Albert Wolff.

#### Meeting Place

Due to rebuilding operations at the W.A. Museum, General Meetings have continued to be held at the Institution of Engineers building 'Science House'. Council has been conferring with the Museum authorities over the possibility of one of the rooms in the old Museum complex being converted into a lecture room which could be used by our Society and could be known as the 'Royal Society Room'. Negotiations are continuing.

#### Library

The library is still housed at the W.A. Museum where, unfortunately, it is no longer accessible to members on the nights of General Meetings. One new exchange was entered into during the year, this was with the Bureau de Recherches Geologiques et Minières for their Bulletin on General Geology. Two hundred dollars was spent on binding.

#### Journal

Four parts of the Journal have been issued during the year, these are volume 54 parts 2-4 and volume 55 part 1. Part 1 included a list of members of the Society.

#### Revision of Constitution

The Constitution, Rules and Regulations of the Society have been completely revised by Council. The draft of this revision will be subject to discussion before being voted upon by members.

#### Garden Island

A submission was made by the President, on behalf of the Society to the Commonwealth Committee on Public Works with regard to the Naval Developments on Garden Island. Hope was expressed that this development would be halted in the central and northern parts of the Island until the potential effects of the general disturbance is investigated.

#### ADVISORY COMMITTEE ON CONSERVATION

*Report by Professor G. A. Bottomley,  
Acting Chairman of the Committee*

Attention throughout the year has been predominantly on the long term development of the Metropolitan environment as foreshadowed in various planning proposals. Whilst prognosis is at best uncertain, there can be no doubt that conservation issues must be given due attention from the earliest planning stages: the Committee has been fully aware of its serious responsibilities in this respect.

Study of the 'Corridor Plan for Perth' (The Metropolitan Region Planning Authority, Perth, 1970) which had been taken up in early 1971 was continued over several meetings. A careful synthesis was prepared from the reports of our sub-Committees on:—

- (a) National Parks and Flora and Fauna Conservation.
- (b) Eutrophication of swamps and lakes.
- (c) Recreational fishing.
- (d) Air pollution.
- (e) Socio-cultural effects of the Plan.

from which emerged a series of Recommendations to the Council embodied in a Report running to twenty-five foolscap pages. This document was substantially endorsed by Council, transmitted to the Premier, Mr. J. Tonkin, and submitted to the Honorary Royal Commission of Enquiry into the Corridor Plan.

In more recent weeks the Committee has commenced examination of the Mr. Paul Ritter's 'An Analytical study of the Proposed Corridor Plan for Perth and possible alternate approach to a regional plan for the Metropolitan Area'.

Advice to the Council has been tendered on developments at Garden Island, and with respect to enquiries from the Environmental Protection Authority's Conservation through Reserves Committee.

The composition of the Committee has varied throughout the current year, Professor R. M. Berndt being Chairman for the earlier meetings. Associate Professor G. A. Bottomley then becoming Acting Chairman for the balance of time, with the following serving or co-opted members: Mr. B. K. Bowen, Professor B. J. Grieve, Mr. A. B. Hatch, Mr. C. F. H. Jenkins, Mr. J. H. Lord, Mr. J. F. Morgan, Mr. L. J. Peet, Dr. P. E. Playford, Dr. W. D. L. Ride, Dr. D. Serventy, Dr. G. M. Storr, Dr. R. W. George, Dr. E. P. Hodgkin, Dr. A. J. McComb, Dr. J. A. Springett.

#### National Trust

Our representative on the Council of the National Trust (Mr. C. F. H. Jenkins), has reported that the Trust has been active in opposing mining in National Parks and in seeking the preservation of the Canning and Swan River foreshores. In these matters its policy has been in line with that adopted by our Society.

#### General

The Society continues to be indebted to the State Treasury and the Government Printer for assistance in publishing the Journal, and to the Western Australian Museum for premises in which to hold Council meetings.

G. M. STORR,  
*President.*

P. G. WILSON,  
*Joint Hon. Secretary.*

# CONTENTS OF VOLUME 55

## Part 1 (published 21st June, 1972)

Paper	Page
1. Spilitic pillow lavas at Mt. Hunt, Western Australia. By J. A. Hallberg	1
2. <i>Erythrobatrachus noonkanbahensis</i> , a Trematosaurid species from the Blina Shale. By J. W. Cosgriff and N. K. Garbutt	5
3. The taxonomic status of small fossil thylacines (Marsupialia, Thylacinidae) from Western Australia. By J. W. J. Lowry	19
Obituary—Eric Mervyn Watson 1903-1971	30

## Part 2 (published 28th November, 1972)

4. The fungus <i>Panus fasciatus</i> (Pleurotaceae) characterised by micro-structure of sporophore and culture. By H. C. Broughton and R. N. Hilton	31
5. A new species of the genus <i>Ramphotyphlops</i> (Serpentes, Typhlopidae) from Western Australia. By J. Robb	39
6. Observations on the Indo-pacific species of <i>Kraussia</i> Dana 1852 (Decapoda, Brachyura). By R. Serene	41

## Part 3 (published 16th April, 1973)

7. An archaeological site in the Chichester Range, Western Australia: Preliminary account. By C. E. Dortch	65
8. The genus <i>Morethia</i> (Lacertilia, Scincidae) in Western Australia. By G. M. Storr	73
9. Prehistoric mammal faunas from two small caves in the extreme south-west of Western Australia. By M. Archer and A. Baynes	80
10. Information on Western Australian earthquakes 1849-1960. By I. B. Everingham and L. Tilbury	90

## Part 4 (published 16th April, 1973)

11. <i>Hakea rubriflora</i> (Proteaceae), a new species from Western Australia. By B. Lamont	97
12. The mygalomorph spider genus <i>Stanwellia</i> Rainbow and Pulleine (Dipluridae) and its relationship to <i>Aname</i> Koch and certain other diplurine genera. By B. Y. Main	100
13. Mulga (North) chondritic meteorite shower, Western Australia. By W. H. Cleverly	115



# 1.—Spilitic pillow lavas at Mt. Hunt, Western Australia

by J. A. Hallberg\*

*Manuscript received 27 July; accepted 21st September 1971*

## Abstract

Spilitic pillow lavas form irregular zones within a sequence of unpillowed high-Mg basalts near Mt. Hunt, Western Australia. These pillows are strongly zoned, alkali-enriched and are petrologically and chemically distinct from the tholeiitic basalts which dominate Archaean volcanic belts throughout the Eastern Goldfields region. It is suggested that the spilitic pillows were derived from lavas similar in composition to the high-Mg basalts of the Mt. Hunt sequence.

## Introduction

Mt. Hunt is 19 km south of Kalgoorlie, to the east of the Kalgoorlie-Kambalda road. Williams (1970) has established the Mt. Hunt sequence as the type area for the Mulgabbie Formation. He suggests a correlation of the Mt. Hunt sequence with a volcanic belt passing through the Corsair, Golden Ridge and Duplex Hill districts. The structure of the area is complex and interpretation is hampered by poor outcrop in critical areas. Essentially, the sequence consists of several belts of NNW-trending, west-facing basalt with intercalated bands of contorted jaspilite. A thick, conformable, west-facing layered sill and several semi-conformable masses of serpentinized ultramafic have been intruded along sedimentary horizons. Discordant porphyry dykes are common and the sequence has been highly folded and faulted, and in places subjected to deep weathering and lateritization.

The massive basalt flows forming the bulk of the sequence are magnesium in nature (8% to 15% MgO) and show the various "quench" textures and skeletal crystal forms which typify this group of basalts throughout the Eastern Goldfields region. Within the stratigraphically older high-Mg basalt flows to the east of Mt. Hunt are several highly altered variolitic horizons and patchy zones where pillows are developed. The best exposure of these pillow lavas is in a small creek bed, 450 m due east of the Mt. Hunt trig point (Figure 1). The pillows range from 0.5 m to 2.5 m in length, and are moderately flattened in the plane of bedding. They are concentrically zoned with mottled greenish cores showing irregular fractures and variolitic margins with closely spaced joints perpendicular to the pillow outline. Dense chilled skins up to 5 cm in thickness surround the pillows. The matrix in which the pillows are set appears to have been a peperite of glassy pillow fragments with some sedimentary material.

## Petrology

Chilled pillow skins are formed of a dense, felted, fine-grained mixture of chlorite, tremolite and clinozoisite. Variolitic pillow margins consist of numerous spherical varioles up to 1 cm in diameter set in a dusted mesostasis of chlorite, clinozoisite, albite and tremolite. The outlines of scattered pyroxene phenocrysts which have been replaced by uraltic can occasionally be seen. The varioles contain radiating sheaves of partially saussuritized plagioclase ( $An_5$ ) intergrown with elongate needles of uraltized pyroxene. A thin selvage of granular pyroxenes replaced by uraltic commonly surrounds the varioles. Pillow cores are filled with up to 65% ragged, randomly oriented lathes of plagioclase ( $An_{5-25}$ ) in a groundmass of chlorite, clinozoisite, tremolite and fine-grained opaques. The plagioclase lathes are water-clear and well twinned.

The mineralogy of these pillows differs markedly from that of tholeiitic pillows throughout the Eastern Goldfields, which are invariably composed of a pleochroic green amphibole and plagioclase with only trace amounts of chlorite, epidote, clinozoisite and quartz (Hallberg, 1971). The composition of the plagioclase in the pillows at Mt. Hunt is more sodic than that in the normal tholeiitic pillows, which contain either a primary labradorite or andesine or a metamorphic oligoclase. There is no indication that the pillows at Mt. Hunt have undergone recrystallization during low-grade regional metamorphism.

## Analytical Data

Fresh samples of the core, margin and matrix of a well-formed pillow in the creek bed exposure were subjected to major and trace element analysis (Table 1). Results indicate that the pillow becomes enriched in Si and Na and depleted in K, Rb, Mg and Fe towards its core; the entire pillow is enriched in volatiles. Ti, Al and most of the less mobile trace elements show little variation across the pillow. This zonation contrasts with the more uniform distribution shown by most tholeiitic pillows in the Eastern Goldfields (Hallberg, 1971). The Mt. Hunt pillow is also enriched in alkalis and volatiles with respect to the tholeiites as shown in Table 1. Perhaps the most unusual feature of the pillow is its high Cr and Ni contents which contrast with previously reported values for both tholeiites and spilites.

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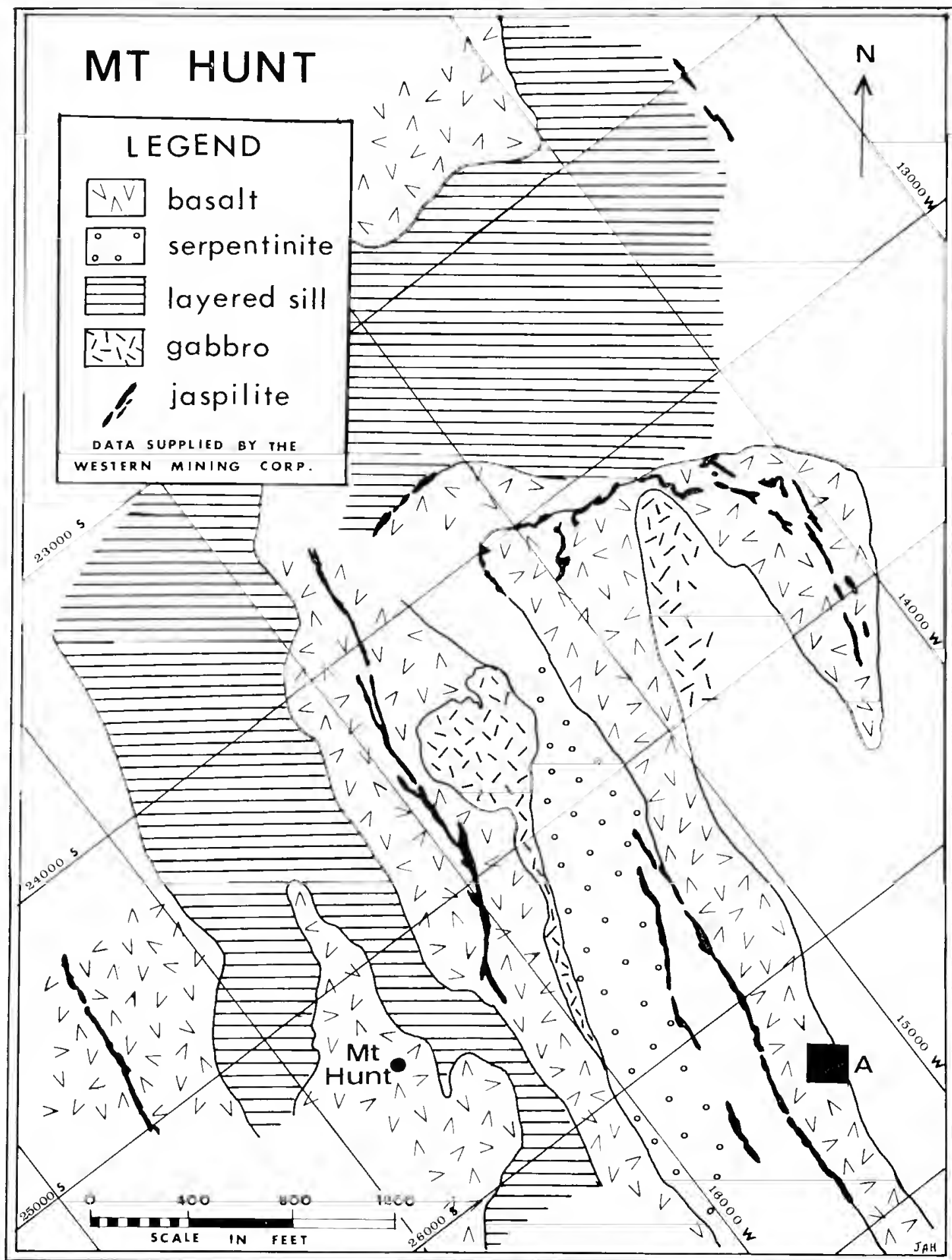


Figure 1.—Geological map of Mt. Hunt and vicinity. Area "A" is the creek-bed exposure of spilitic pillow lavas.

TABLE 1

Analysis of spilitic pillow lavas from Mt. Hunt

	1	2	3	4	5	6	7
SiO <sub>2</sub>	46.25	54.48	57.10	51.4	52.81	49.6	48.33
Al <sub>2</sub> O <sub>3</sub>	16.12	14.25	16.85	14.8	13.42	16.0	15.44
Fe <sub>2</sub> O <sub>3</sub>	2.51	2.29	2.48	1.5	2.27	3.8	
FeO	9.45	7.75	3.76	9.1	7.40	6.1	8.58*
MgO	9.96	8.07	4.35	6.7	9.81	5.1	7.41
CaO	7.63	6.99	6.77	10.7	9.12	6.6	8.02
Na <sub>2</sub> O	0.67	0.93	5.12	2.7	1.94	4.3	4.96
K <sub>2</sub> O	1.54	1.03	0.06	0.18	0.43	1.28	0.72
H <sub>2</sub> O +	3.72	2.98	1.92	1.0	1.79	3.4	
H <sub>2</sub> O -	0.41	0.19	0.69		0.25		
CO <sub>2</sub>	0.33	0.35	0.10	0.1	0.25	1.63	
TiO <sub>2</sub>	0.77	0.75	0.74	0.92	0.60	1.57	0.59
P <sub>2</sub> O <sub>5</sub>	0.11	0.08	0.08	0.13	0.12	0.26	
MnO	0.28	0.23	0.14	0.21	0.16	0.15	
Total	99.75	100.47	100.16				

Co	90	71	59	59	65
Cr	817	891	841	395	901
Cu	103	97	82	98	67
Ni	285	222	280	161	243
Rb	66	41	4	9	8
Sr	90	95	92	105	176
Y	37	33	22	22	17
Zn	176	138	99	112	71
Zr	68	66	67	60	71

Q	—	14.2	6.9	0.8	5.3
or	9.5	6.3	0.3	1.0	2.6
ab	5.9	8.1	44.5	23.5	16.4
an	38.1	32.8	23.4	28.0	27.3
di	wo 0.3	1.0	4.3	10.4	7.5
	en 0.2	0.6	2.9	5.4	4.8
	fs 0.1	0.3	1.0	4.6	2.2

hy	en 23.6	20.1	8.1	11.6	19.8
	fs 13.8	11.6	2.9	9.9	9.1

ol	fo 1.5	—	—	—	—
	fa 0.9	—	—	—	—

mt	3.8	3.4	3.7	2.2	3.2
il	1.5	1.4	1.4	1.7	1.1
ap	0.2	0.2	0.2	0.3	0.2

1 matrix, spilitic pillow, Mt. Hunt, W.A.

2 margin, spilitic pillow, Mt. Hunt, W.A.

3 core, spilitic pillow, Mt. Hunt, W.A.

4 average Eastern Goldfields tholeiitic basalt (Hallberg, 1971).

5 average of five high-Mg basalts, Mt. Hunt, W.A.

6 average spilite (Vallance, 1960).

7 average of 53 spilites, Virgin Islands (Hekinian, 1971).

CIPW norms calculated on a volatile-free basis.

\* Total Fe as FeO.

## Affinities

In morphology, mineralogy and chemistry the Mt. Hunt pillows are similar to reported spilites. Vallance (1960, p. 22) notes that "Variolitic textures are common in many spilites . . .", and that "Amygdules and veins appear in almost all recorded spilites but unfilled cavities, on the other hand, are rare". Bailey *et al.* (1964) describe similar pillows from the Franciscan Formation of California and Hekinian (1971), highly variolitic pillows from the U.S. Virgin Islands. Amstutz (1967) and Hekinian (1971) list albite, chlorite, epidote, calcite and iron oxides as the major constituents of volcanic spilites. Spilites may contain a calcic augite or salite. Vallance (1960) maintains that the only distinguishing chemical characteristic of spilites is their high volatile content. In this respect it should be noted that the volatile content of the Mt. Hunt pillow is much greater than that of the average Coolgardie-Norseman basalt (Table 1). Spilites also tend to be enriched in

alkalis (Amstutz, 1967). Chemically, the pillow from Mt. Hunt compares closely with spilite analyses reported by Vallance (1960) and Hekinian (1971), as shown in Table 1, and with pillows from the Franciscan Formation (Bailey *et al.*, 1964), as shown in Figure 2. On the basis of these similarities it is concluded that the pillowed units at Mt. Hunt represent true spilites.

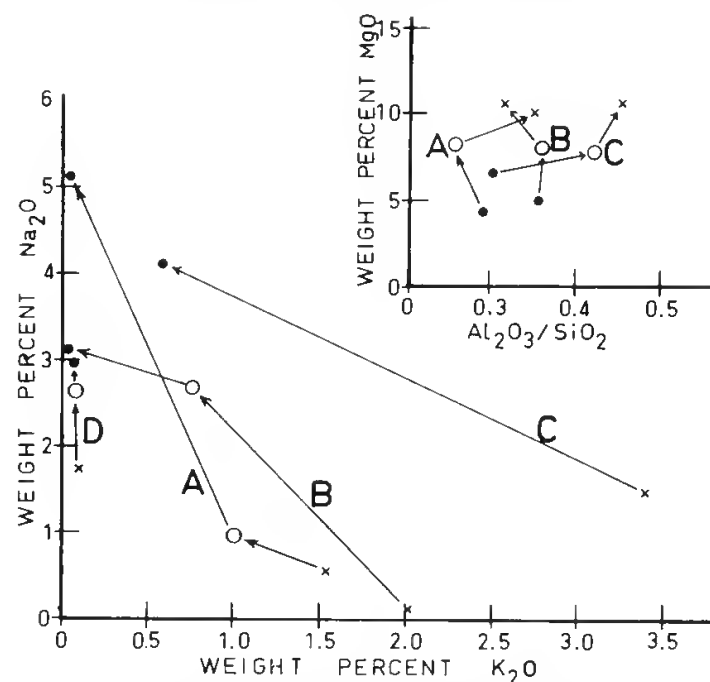


Figure 2.—Major oxide variations in spilitic pillow, Mt. Hunt. A = spilitic pillow, Mt. Hunt, B and C = spilitic pillows from the Franciscan Formation of California (Bailey *et al.* 1964), D = tholeiitic pillow, Norseman, W.A. (Hallberg, 1970). Solid circles indicate pillow cores, open circles pillow margins and x's pillow matrices.

## Discussion

Archaean spilites have been reported from Sweden and India (Vallance, 1960) and from South America (Williams *et al.*, 1967). Although Archaean "greenstones" from Western Australia have been collectively referred to as spilites (Prider, 1948, 1961), this usage follows the assumption that all metamorphosed Archaean pillowed basalts are spilites, a supposition which is certainly not true for examples from Western Australia (Hallberg, 1970). The Mt. Hunt pillows may represent an isolated case of spilite development; a regional investigation of Archaean volcanic belts has disclosed no similar occurrence (Hallberg, 1970).

Spilitic magmas, autometasomatism, reaction with sea water and post-consolidation alteration have been proposed as mechanisms for producing spilites (Vallance, 1960). Some indication of the nature of the magma from which the spilites at Mt. Hunt were derived is given by their high concentration of Cr, Ni and Mg. It is unlikely that Cr and Ni could have been added to the pillows by any of the mechanisms mentioned; it can therefore be concluded that these values reflect the composition of the melt from which the pillows formed. The Cr and Ni values for the spilitic pillows are identical to those in the associated high-Mg basalts (Table 1). It is therefore postulated that the pillows were

formed from a high-Mg basalt magma and that spilitization occurred during or after pillow formation. The association of high-Mg basalts, layered sills, intrusive ultramafics and pelitic sediments is believed to represent a sequence of oceanic crustal material (Hallberg and Williams, unpublished data). That spilites can develop in such an environment is attested to by their presence in some Alpine sequences (Vallance, 1960). Perhaps the most important, and yet unanswered, question is why similar spilitic rocks have not developed in other volcanic belts in the Eastern Goldfields region deposited in similar environments.

#### Acknowledgements

The author is indebted to the Western Mining Corporation for stimulating an interest in the area and providing information on the geology of Mt. Hunt. Acknowledgement is also made to Dr. D. R. Hudson and to Mr. D. A. C. Williams for their criticism of the manuscript.

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## 2.—*Erythrobatrachus noonkanbahensis*, a Trematosaurid species from the Blina Shale

by John W. Cosgriff \* and Neil K. Garbutt †

Manuscript received 27 July, 1971; accepted 19 October, 1971

### Abstract

*Erythrobatrachus noonkanbahensis*, a new temnospondyl of the family Trematosauridae, is based on three skull fragments collected at a locality in the Lower Triassic Blina Shale of the Fitzroy Trough in Western Australia. A partial restoration of the skull accomplished from these fragments indicates that the taxon belongs to the group of trematosaurids characterized by elongate, narrow skulls that includes *Aphaneramma*, *Gontiglyptus*, *Stochiosaurus* and *Wantzosaurus*. Although it is clearly and equally distinct from all of these the general relationship suggests an early Scythian age for the new form. This age is consonant with the basal Scythian stratigraphic position of the Blina Shale vertebrate fauna established by a variety of fossil evidence.

### Introduction

The three skull fragments that comprise the hypodigm of *Erythrobatrachus noonkanbahensis* are all extremely weathered, broken and incomplete. They were collected from the surface of the fossil locality, U.C.M.P. V6044 on Noonkanbah Station in the West Kimberley District (Cosgriff, 1969, fig. 1). The holotype, W.A.M. no. 62.1.46, and one topotype, W.A.M. no. 62.1.50, were found about 100 yards apart in July, 1960, by a joint field party of Western Australian Museum and the University of California, Berkeley. The second topotype, W.A.M. 71.6.22 was found by the senior author in July, 1965, during a field trip of the Department of Zoology and Comparative Physiology, Monash University, near the spot where W.A.M. no. 62.1.50 had been found five years before. W.A.M. nos. 62.1.46 and 71.6.22 are internal matrix casts from which most of the surface bone has been eroded. They retain, however, such features as traces of the sutures separating bones and casts of openings and foramina that project in relief from the core surfaces. W.A.M. no. 62.1.44 (fig. 1) is from the central region of a skull and includes partial casts of both orbits. W.A.M. no. 71.6.22 (fig. 2) is from the right posterolateral corner of a skull considerably smaller than that of the holotype. The other specimen, W.A.M. no. 62.1.50 (fig. 3) is an external impression from the palatal surface of the snout region of an individual somewhat smaller than that represented by the holotype. The impression, retained on a piece of shale matrix, shows two pairs of parallel tooth rows and a few sutures.

Although the three specimens derive from different portions of skulls not comparable in size and were found widely separated from each other there is little doubt that they are homotaxial. All are from elongate, narrow skulls. Such features as orbits, internal nares and interpterygoid vacuities closely match in general outline and relative size when compensation is made among them for overall size. In following passages each of the specimens is described separately, following which the restoration of the skull is discussed and compared with skulls of other trematosaurids.

This report is the fourth in a series appearing in this journal dealing with the vertebrate fauna of the Lower Triassic Blina Shale. The first report (McKenzie, 1961) provides a detailed description of the lithology of the unit at the vertebrate localities, a map of certain localities and an analysis of the depositional environment. The second (Cosgriff, 1965) is a consideration of the rhytidosteid temnospondyl, *Deitasaurus kimberleyensis* and the third (Cosgriff, 1969) a consideration of the brachyopid temnospondyl, *Blinasaurus henwoodi*. All three contain information on the geographic and stratigraphic positions of all of the vertebrate localities, on the total fauna and flora of the unit and on the history of collecting at the localities. In addition, the second report considers the nature of preservation of the vertebrate faunas recovered from Upper Permian and Lower Triassic units found in other parts of the world. For more detail on the general geology and stratigraphy of the unit the reader is referred to Guppy *et al.* (1958), McWhae *et al.* (1958), and Veevers and Welles (1961).

This report concludes studies on the Temnospondyli of the Blina Shale fauna. Remaining undescribed vertebrate material in the W.A.M. and U.C.M.P. collections consists mainly of scanty, incomplete and poorly preserved fish remains but also includes some large chunks of bone, perhaps from an ichthyosaur, and some enigmatic bony plates whose allocation, even to class, is uncertain. Among the fish material are tooth plates of *Ceratodus*, skull parts of *Saurichthys* and a coelacanthid and a trunk impression of an actinopterygian. Some discrepancy will be noted between these statements and the faunal listings provided by the author in the two previous accounts. The 1965 paper (p. 89) notes the presence of "... trematosaurids which are perhaps congeneric with *Aphaneramma* and *Tertrema* of the Posidonomya Beds," and the

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1969 paper (p. 65) mentions "... a capitosaurid, two trematosaurids." The "*Tertrema*" of the 1965 report is actually W.A.M. no. 62.1.44 now described as the holotype of *Erythrobatrachus noonkanbahensis*, and the "*Aphaneramma*" is W.A.M. no. 62.1.50, one of the topotypes of this species. The two trematosaurids mentioned in the 1969 paper are also these two specimens. The comparisons of the two with W.A.M. no. 71.6.22, found later, establishes the homotaxy of all three and, together, they seem sufficient to form the basis for the new genus and species. The capitosaurid noted in 1969 is a lower jaw which, on further analysis, seems to be referable to *Deltasaurus kimberleyensis*.

### Order Temnospondyli

This order constitutes the principal group of the Labyrinthodontia during the interval Carboniferous through Triassic and has been extensively reviewed and classified by Case (1946), Romer (1947), Säve-Söderbergh (1935) and Watson (1919). The partial classification here adopted which concerns the Trematosauroidae is an amalgamation of Romer (1947), Säve-Söderbergh (1935), Welles and Cosgriff (1965) and Cosgriff (1965). In this the suborders of the Temnospondyli are abandoned and the various superfamilies including the Trematosauroidae are placed directly under the order. Romer (1947) divided the contents of the order among four suborders, Ichthyostegalia, Rhachitomi, Trematosauria and Stereospondyli; later (1966), he modified the classification considerably, removing the Ichthyostegalia to a separate order, denoting the Trematosauria to a superfamily (Trematosauroidae) of the Stereospondyli and retaining this last with the Rhachitomi as the only two suborders of the Temnospondyli. Welles and Cosgriff (1965), following Säve-Söderbergh (1935), abandoned these last as formal groupings, noting that: "... the line of separation between the two suborders based on the nature of the vertebrae is not so clear as was once supposed. Various members of the Stereospondyli exhibit intermediate conditions between rhachitomous and stereospondylous ossification." This variation may be observed even among genera of a single superfamily as in the Capitosauroidae. Further, as both Säve-Söderbergh and Welles and Cosgriff point out, the Triassic Stereospondyli seem to be a highly polyphyletic group possessing points of origin among a number of different groups of Permian Rhachitomi.

### Superfamily Trematosauroidae

The superfamily, as here considered, parallels Romer's (1947) Suborder Trematosauria in being monothalax, containing only the family Trematosauridae. Romer (1966), however, followed the author (1965) in part by removing the genera *Pellostega* and *Rhytidosteus* from the Trematosauridae and placing these with *Deltasaurus* in the reconstituted family Rhytidosteidae (von Huene, 1920). The two classifications diverge at this point, though, as Romer included the Rhytidosteidae as a second family of the Trematosauroidae and Cosgriff assigned

it to a new superfamily, Rhytidosteioidea which appears to be closely allied to the Rhinesuchoidea.

**Definition.** Romer, (1947, p. 314) provided a diagnosis of the Suborder Trematosauria which may be transferred to the Trematosauroidae and also applied to the Trematosauridae as the only contained family. Much of the diagnosis is differential in type including some characters that are typical of the entire Order Temnospondyli and some that are typical of the Triassic members of the order. The definitive characters of his diagnosis that serve to distinguish the Trematosauroidae from the other superfamilies of the order include the following:

"Skull not depressed but relatively high and narrow; triangular in shape with pointed snout; frequently elongate both pre- and post-orbitally."

"Body of the parasphenoid developed as a broad and elongate plate extending backward below occipital region; fused basal articulation exhibits long suture between parasphenoid and pterygoid."

"Exoccipital-ptyergoid contact present but not visible ventrally."

The diagnosis of the family provided by Säve-Söderbergh (1935, p. 87) concurs with that of Romer in most respects although it expresses the above characteristics in different terms. One character listed in this that should be added to the above is:

"Processus cultriformis of the parasphenoid very high and narrow."

All of these characters could probably be validated through quantitative comparisons among the superfamilies of the Temnospondyli. This, however, would be beyond the scope of the present paper and they are accepted for the present purpose of determining the taxonomic position of the new form from the Blina Shale.

### Family Trematosauridae

The Trematosauridae, confined to the Lower Triassic (and perhaps, the uppermost Permian), occur in continental deposits of Arizona, Germany, Russia and South Africa and in marine or marginal deposits of Australia, Greenland, India, Madagascar and Spitzbergen. The family seemingly experienced a considerable evolutionary radiation just before and during its short range in the stratigraphic record. In number of genera it is the largest of the Temnospondyl families of the Triassic. These genera although showing great diversity in skull shape and proportions obviously constitute a natural and well-defined group through the distinctive features set forth in diagnoses of Romer and Säve-Söderbergh.

The osteology of the skull and the lower jaw of several of the better-known species has been thoroughly studied and well-documented by a number of investigators. A review of this work together with excellent summaries of the morphology of the species has been provided by Romer (1947).



*Contents of the family.* The species reviewed by Romer (1947) and considered by him to be valid taxa of the Trematosauridae include: *Trematosaurus brauni* (Burmester, 1849) from the middle Buntsandstein of Western Germany; *Trematosaurus* sp. (Sushkin, 1927) from Zone VI of the Cis-Uralian region of the U.S.S.R.; "*Trematosaurus*" *kannemeyeri* (Broom, 1909), *Trematosuchus sobeyi* (Haughton, 1915), *Microsaurus casei* (Haughton, 1925) and *Rhytidosteus capensis* (Owen, 1884), all from the Cynognathus Zone of South Africa; *Aphaneramma rostratum* (Woodward, 1904), *Peltostega erici* (Wiman, 1916), *Peltostega wimani* (Nilsson, 1946), *Platystega depressa* (Wiman, 1915), *Lyrocephalus euri* (Wiman, 1914) and *Tertrema acuta* (Wiman, 1915), all from the Sticky Keep Formation of Spitzbergen; *Lyrocephalus koehi* (Säve-Söderbergh, 1935) and *Stochiosaurus nielsenii* (Säve-Söderbergh, 1935), both from the Woody Creek Formation of Greenland; *Gonioglyptus longirostris* (Huxley, 1965) from the Panchet beds of Bengal, India; and *Gonioglyptus kokeni* (Huene, 1920) from the Prionolobus beds of the Salt Range of India. Most of these species are based on adequate cranial material but "*Trematosaurus*" *kannemeyeri* and *Gonioglyptus longirostris* are, as Romer notes, dubious taxa founded on very fragmentary specimens. The species of *Peltostega* and *Rhytidosteus* as noted in a previous section, have been removed from the family.

Species that have been described since 1947 and that are added to the family in Romer's (1966) text include: *Inflectosaurus amplus* (Shishkin, 1960) from Zone V of the Cis-Uralian region of the U.S.S.R. and *Wantzosaurus elongatus* (Lehman, 1961) from the Middle Sakmena beds of Madagascar. This listing also includes with question *Laidleria gracilis* (Kitching, 1957) from the Cynognathus Zone of South Africa. Kitching placed this form in its own family under the Stereospondyli and the senior author (1965) suggested that this family, Laidleriidae, could be included provisionally in the Rhytidosteidae.

Lehman (1966) added the following species from the Middle Sakmena beds to the family: *Trematosaurus madagascariensis*; *Aphaneramma* sp.; *Ifasaurus elongatus*; and *Lyrosaurus australis*. Of these, only the first appears to be a valid taxon founded on adequate material. *Ifasaurus elongatus* and *Aphaneramma* sp., although trematosaurids without doubt, are based on skull fragments with a few distinctive features. *Aphaneramma* sp. resembles *Wantzosaurus elongatus*. *Lyrosaurus australis* closely resembles *Mahavisaurus dentatus*, a form described and illustrated by Lehman in this paper which, however, he placed with question in the Rhinesuchoidea.

#### **Erythrobatrachus,\* gen. nov.**

*Type species.* *Erythrobatrachus noonkanbahensis*.

*Differential diagnosis.* A long-snouted, slender-skulled trematosaurid (allied to *Aphaneramma*

*rostratum*, *Gonioglyptus kokeni*, *Stochiosaurus nielsenii* and *Wantzosaurus elongatus*) with proportionately small interpterygoid vacuities distinguishing it from all of these—length of interpterygoid vacuities as measured on midline only about three-fourths of length of posterior part of skull roof as measured on midline from level of anterior borders or orbits to posterior edge of skull roof. It is further distinguished from *A. rostratum* and *W. elongatus* through being relatively short and broad in the region of the skull roof bounded by orbits, external nares and lateral skull margins—width of skull across anterior margins of orbits between eight-tenths and nine-tenths of length as measured on midline between anterior borders of orbits and posterior borders of external nares. It resembles *A. rostratum* and *W. elongatus* but differs from *G. kokeni* and *S. nielsenii* in showing very little increase in skull width posterior to the orbits—width of skull across posterior margins of orbits about eight-tenths of greatest width of skull across posterolateral corners. Lateral margins of skull bulged outward in orbital region following curvature of orbit lateral borders as in *G. kokeni*, a feature not observed in the other three species.

#### **Erythrobatrachus noonkanbahensis, sp. nov.**

*Holotype.* W.A.M. no. 62.1.46, an internal matrix cast of the central region of a skull.

*Type locality.* U.C.M.P. locality V6044. Noonkanbah Station, West Kimberley District, Western Australia. The approximate position is shown on a map in Cosgriff (1969, Fig. 1, p. 66) and it is the same locality as the site listed by McKenzie (1961, p. 73, Table II, ninth entry) as: "Bore G, Noonkanbah Station, 124° 45' E., 18° 20' S." To reach the site drive about 15 miles south from Calwynyardah homestead on the station road leading to Noonkanbah homestead to a spot where a fence and fence road cross the station road. Turn east onto the fence road and drive about  $\frac{3}{4}$  mile. The locality, which lies about  $\frac{1}{2}$  mile north of this point, is a low rounded hill approximately 150 yards in diameter. To give another reference point, it lies about  $1\frac{1}{2}$  miles N70E from Noonkanbah Station Bore no. 20 which is on the west side of the Calwynyardah-Noonkanbah Station road. The hill is capped with a remnant of the Quaternary Warrimbah Conglomerate and its flanks are covered with a scree of pebbles of varied lithology which become smaller in size and more widely spaced toward the base of the hill. Some of the pebbles closely resemble samples of the Blina Shale from the Erskine Range; some resemble samples of the Erskine Sandstone from this area; and some have been ferruginised beyond recognition.

*Horizon.* Blina Shale, the upper portion of this unit, Otoceratan Division of the Scythian State.

*Topotypes.* W.A.M. no. 71.6.22 an internal matrix cast of the right posterolateral portion of

\*Genus name from Gr.: erythro-red, plus, batrachos-frog; it is given in reference to the iron-stain colour of the specimens.

a skull. W.A.M. no. 62.1.50, the impression of the palatal surface of the snout region of a skull, broken off across the anterior margins of the internal nares.

*Diagnosis.* As for genus.

#### Description

W.A.M. no. 62.1.46. The type specimen, primarily a matrix core, is derived from the central region of a skull. It is broken off through the centers of the orbits and immediately posterior to the external nares. The impressions of dermal bones are retained on the dorsal and palatal surfaces. Internal sutures are marked by serrate ridges in low relief. The matrix casts of the anterior portions of the orbits and interpterygoid vacuities and the cylindrical infillings of various small foramina project from the core surface.

A fragment of dermal bone remains on each side of the core of the rostrum. The fragment on the left side is the more extensive and includes parts of the maxillary and palatine bones. The palatal surfaces of these bones abut the edges of the core and enclose the entire left choana.

A patch of eroded bone covered a small area of the dorsal surface anterior to the left orbit. This was removed in order to locate the internal sutures on this part of the core.

The internal core rapidly narrows from the centers of the orbits to a constriction midway between the orbits and external nares. The specimen widens abruptly anterior to this constriction but much of this width is contributed by the fragments of dermal bone on the sides of the rostral core. The rostral core, itself, gradually decreases in width anterior to the constriction. The constriction of the snout was probably reflected in a more moderate fashion, on the external surface of the original skull.

*Dorsal surface* (fig 1a). The orbital casts have oval anterior borders. They lie close to the lateral edges of the core. The cast of the left orbit is more complete and has an everted rim. The dermal bone surrounding the left orbit was 5-6 mm. thick.

The frontal impressions are of nearly even width from front to back and are excluded from the medial margins of the orbits by the postfrontal and prefrontal impressions. The frontal-nasal sutures are quite jagged.

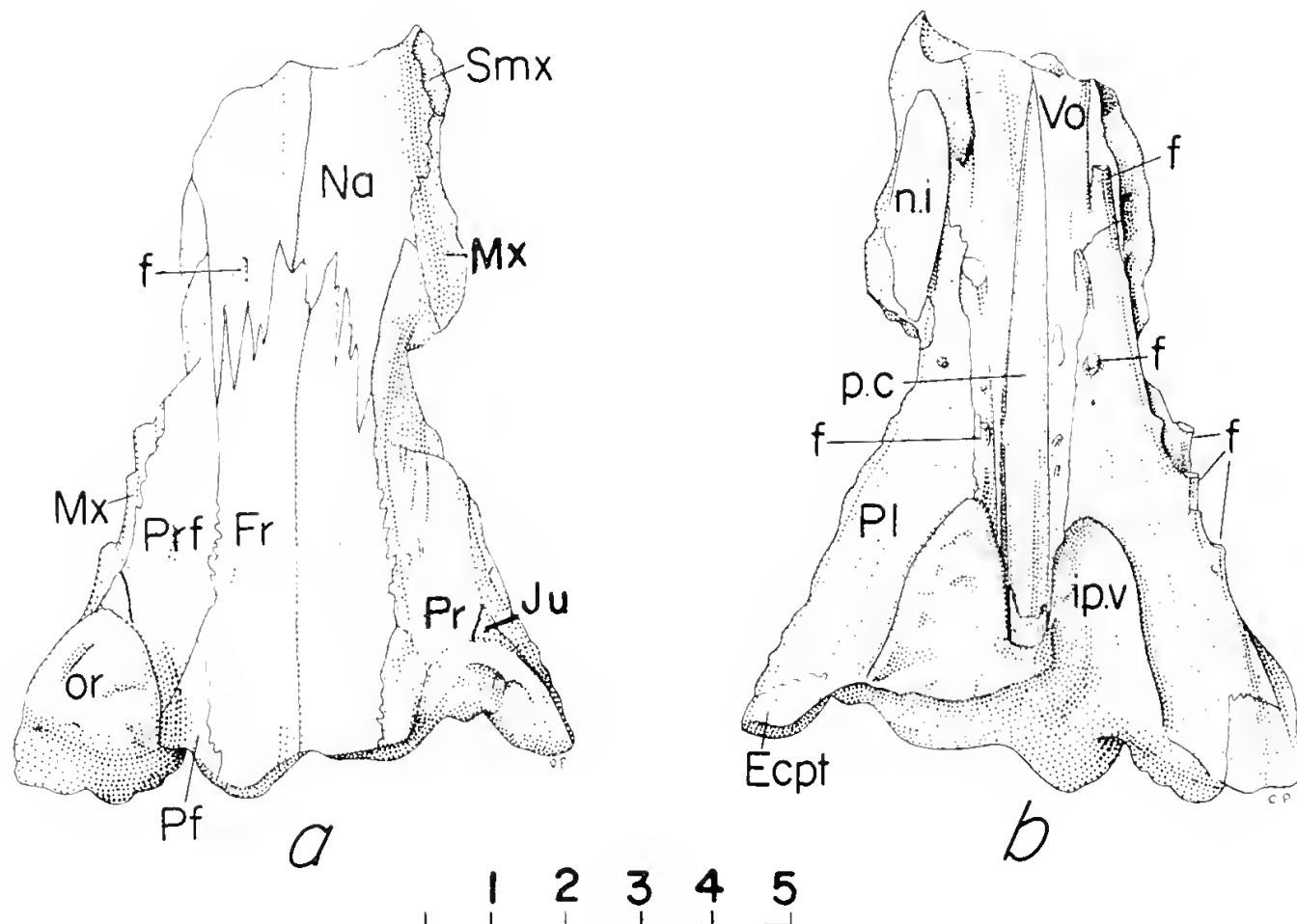


Figure 1.—*Erythrobatrachus noonkanbahensis*, gen. et sp. nov., holotype, W.A.M. no. 62.1.46; a, dorsal view; b, ventral view.

Abbreviations for Figure 1 and following Figures: Ec, Ecpt, ectopterygoid; Eo, exoccipital; f, foramen; f.p, parietal foramen; fl, descending flange of postfrontal; fo, st, subtemporal fossa; Fr, frontal; ip. v, interpterygoid vacuity; Ju, jugal; Mx, maxillary; max. t, maxillary teeth; n.e, external nares; n.i, internal nares; Na, nasal; or, orbit; P, parietal; p.c, cultriform process of parasphenoid; pal. t, palatine tusk; Pf, postfrontal; Pl, palatine; Pm, premaxillary; Po, postorbital; Pp, postparietal; Pr, Prf, prefrontal; Ps, parasphenoid; Pt, pterygoid; Qu, quadrate; Quj, quadratojugal; Smx, septomaxillary; Sq, squamosal; St, supratemporal; Tab, tabular; Vo, vomer.



The nasal impressions are broader than the frontal impressions. The internasal suture is off-set to the left of the interfrontal suture. The right nasal impression is laterally bordered by the impressions of the prefrontal, maxillary and septomaxillary bones. The left nasal has the cylindrical infillings of two small foramina projecting from its surface.

The prefrontal impressions form the antero-medial borders of the orbits. They have medial sutures with the postfrontal and frontal impressions and lateral sutures with the jugal and maxillary impressions. They have pointed anterior borders which are level with the anterior terminations of the frontal impressions.

Only the anterior corners of the postfrontal and jugal impressions are present on the dorsal surface. They are laterally bordered by the maxillary impressions. The postfrontal impressions form the medial margins of the orbits. The jugal impressions form the lateral and anterolateral borders of the orbits.

Narrow strips of maxillary impression lie along the lateral edges of the core. Two of these strips flank the prefrontals and jugals in the posterior portion of the specimen. A third piece of maxillary impression lies lateral to the right nasal impression. The maxillary impression of the left side has three large infillings projecting forward along its lateral edge; these perhaps represent foramina for branches of nerve V2.

The posterior apex of the right septomaxillary rests on the maxillary fragment and is medially bordered by the nasal impression. The septomaxillary is never an extensive bone and the external nares must have lain close to the broken anterior margin of the core.

*Palatal surface* (fig. 1b). Only the anterior portions of the interpterygoid vacuity cores are preserved. They are narrow with rounded anterior borders. The dermal bone at the anterior border of the right vacuity was 1-2 mm. thick.

The right choana is a symmetrical opening, 2.6 cm. long and 0.6 cm. wide across its center. It is enclosed within the fragments of the maxillary and palatine bones and lies close to the lateral edge of the internal core.

The impression of the cultriform process of the parasphenoid runs up the center of the palatal surface. The termination is level with the anterior edge of the choana. The anterior portion of the cultriform process had a flat upper surface. Posterior to the region of the choana the upper surface becomes progressively more concave. Most of the left parasphenoid-vomer suture is clearly marked.

Each vomer-palatine suture follows an irregular course from the medial edge of the choana back to the antero-medial border of the interpterygoid vacuity. The impressions of the vomer and palatine bones are rippled and striated, reflecting the texture of the upper surfaces of the bones.

The impression of the left vomer extends down the length of the fragment lateral to the

parasphenoid impression. The anterior and posterior edges of the impression are missing. It is flat-lying in the region medial to the choana. Posteriorly, the vomer impression narrows and becomes vertical on the medial border of the interpterygoid vacuity. The position of this portion of the vomer impression between parasphenoid impression and interpterygoid vacuity shows that the cultriform process of the parasphenoid was flanked by processes of the vomer bones.

Two forwardly-directed cylinders of which the anterior is the largest protrude from the surface of the vomer impression just within the left vomer-palatine suture. One or both of these may correspond with the foramen of *Lyrocephalus euri* which Säve-Söderbergh (1936, figs. 4 & 5) labelled "the posterior opening in the vomer for the palatine nerve".

The anterior terminations of the palatine impression lie on the medial sides of the choanae. Posteriorly, the impressions are limited by the broken edges of the core and by the anterior corners of the ectopterygoid impressions. The lateral edges of the palatine impressions could not be located and the relationships with the maxillary impressions and the impressions of other bones of the skull roof are unknown.

Each palatine impression has a small round protuberance posterior to the choana. These are infillings of foramina which may correspond to the *foramina recti palatonasalis* of *Lyrocephalus euri* and *Aphaneramma rostratum*, so designated by Säve-Söderbergh (1936, figs. 4, 5 and 34).

A small portion of ectopterygoid impression remains on each posterolateral corner of the palate surface. The left impression is the largest. It has a rounded anterior border with a tightly serrate suture on the palatine impression.

W.A.M. no. 71.6.22. This specimen, a second matrix core, is derived from the right posterolateral region of a skull. The individual represented by this fragment was considerably smaller than the individual represented by the holotype, probably less than half its size. The fragment ends anteriorly at an irregular break that crosses the dorsal surface just anterior to the posterior margin of the right orbit and that crosses the palatal surface through the approximate centre of the right interpterygoid vacuity. The broken medial surface is also quite irregular but, in general, slopes dorsolaterally so that the preserved portion of the palatal surface is more extensive than the preserved portion of the dorsal surface. The lateral and posterior edges are, for the most part, the complete, natural edges of the matrix core although the posterior portion of the lateral edge, the part bordering the subtemporal fossa, is chipped in a few places.

The dorsal surface is entirely internal cast portraying the nearly smooth inner surface of the skull roof with sutures marked as a slightly raised ridges. The occipital surface contains only the right posterior cheek wall, largely composed of internal cast surface but retaining a part of the quadrate bone ventrally. The

palatal surface was originally covered by hematite-rich matrix. This was prepared off, revealing the nearly complete subtemporal fossa. the posterior half of the interpterygoid vacuity and large parts of the parasphenoid, pterygoid and quadrate bones. The latter are poorly preserved and splintery. The medial surface is a break crossing the right lateral area of the braincase.

**Dorsal surface** (fig. 2A). The smooth internal cast surface curves sharply down from the broken medial edge to the lateral margins. The posterior margin, formed completely by the edges of the quadratojugal and squamosal bones, is slightly convex posteriorly. From this point, the dorsal surface narrows gradually forward to the posterior margin of the orbit.

Only one complete and four partial impressions occupy the dorsal surface. The postorbital impression is of nearly even width from its smoothly curved border on the right orbit to its posterior termination. It ends at the medial break surface, probably just lateral to its original sutural border on the postfrontal and supratemporal impressions. Laterally it ends with sutural traces separating it from the jugal and quadratojugal impressions.

The squamosal is the largest impression, making up nearly a third of the dorsal surface of the specimen. It has extensive sutural contact with the quadratojugal, jugal and postorbital as shown in the illustration. As with

the postorbital it has a jagged medial edge, being broken off just lateral to its sutural union with the supratemporal and tabular elements.

Only the posterior part of the jugal impression is retained. It forms the lateral and part of the posterior margins of the orbit and, from these, extends back to a sutural trace separating it from the quadratojugal. Its medial edge on the subtemporal fossa is somewhat chipped.

The surface of the quadratojugal, the only complete impression on the dorsal surface, extends from the jugal sutural trace to the posterior edge and from the margin of the subtemporal fossa to the squamosal sutural trace.

A small corner of the postfrontal impression is probably present posterior to the orbit margin and anterolateral to the postorbital as this is part of the area of the skull normally occupied by the postfrontal in temnospondyls. However, a sutural trace dividing it from the postorbital is not retained.

**Palatal surface** (fig. 2B). This surface, in a fair state of preservation, is broken off laterally just to the left side on the cultriform process and, anteriorly, through the centre of the interpterygoid vacuity.

The two most prominent features of the palatal surface are the interpterygoid vacuity and the subtemporal fossa. The preserved part of the interpterygoid vacuity is long and narrow. It has a straight medial margin throughout and the lateral margin is very slightly convex in its anterior part. The posterior part of the lateral margin is slightly indented by the convex edge of the palatal ramus of the pterygoid bone. The width of the vacuity is 17 mm. at its broken anterior edge and only 7 mm. in the area where it is indented by the pterygoid.

The subtemporal fossa appears as an elevated matrix platform due to the loss of most of the surrounding bone. It is long and narrow as is usual for the trematosaurids, measuring 39 mm. in maximum length and 13 mm. in maximum width. The lateral border, formed by the quadratojugal and jugal, is nearly straight and the medial border, formed by the pterygoid, is slightly concave on its anterior half and straight on its posterior half. The anterior margin which lies about 10 mm. anterior to the posterior margin of the interpterygoid vacuity is evenly rounded. The posterior border is formed by a poorly preserved portion of the quadrate condyle and is inclined diagonally in a posterolateral direction.

Besides the quadrate the only bone preserved on the palatal consists of portion of the parasphenoid and the right pterygoid. The parasphenoid portions include the right lateral part of the basal plate and the posterior part of the cultriform process. The approximate position of the parasphenoid-ptyergoid suture is indicated by a change in direction of bone grain and runs posterolaterally from the posterior margin of the interpterygoid vacuity to the broken posterior edge of the specimen. The cultriform process, a very narrow structure as in all trematosaurids, is poorly preserved with edges that are discontinuous and indistinct in places.

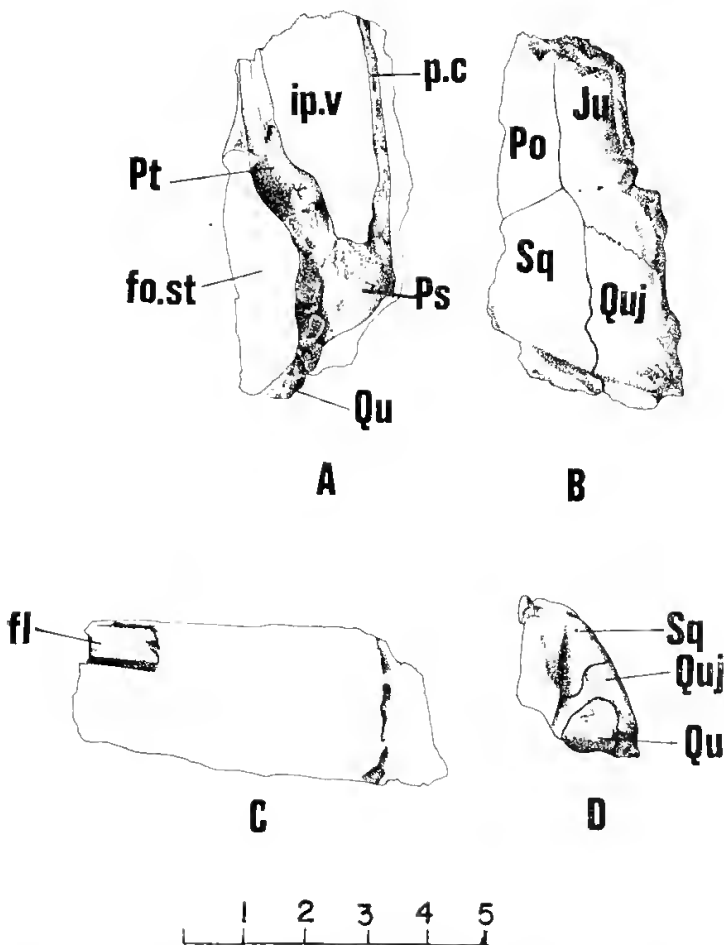


Figure 2.—*Erythrobatrachus noonkanbahensis*, gen. et sp. nov., topotype, W.A.M. no. 71.6.22. A. ventral view; B. dorsal view; C. medial view; D. occipital view.

**Occipital surface** (fig. 2C). The internal impression of the posterior cheek wall retaining a weathered remnant of the quadrate bone is the only portion of this surface retained on the specimen. In rear view this impression is triangular in outline with an apex at the locus of the missing otic notch and slightly concave in shape. It lies in a plane nearly normal to the dorsal surface of the specimen and slopes posteriorly, ventrally and laterally to the region of the articular surface of the quadrate bone. The lateral edge meets the dorsal surface impression at nearly a right angle and the medial edge is free, forming the lateral margin of the pteroccipital fenestra. The clearly marked trace of the squamosal-quadratojugal suture runs transversely across the middle of the impression surface. The remnant of quadrate bone is missing all of its surface and is nothing more than an irregular lump of ferruginized material occupying the ventral part of the concavity of the cast surface.

**Medial surface** (fig. 2D). The only feature identified with certainty on this surface is the impression of the descending flange of the right postfrontal bone. (See Säve-Söderbergh, 1936, fig. 10 for a portrayal of this structure in *Lyrocephalus euri*.) It is a cylindrical, medially convex structure, 14 mm. in length and 8 mm. in depth. It slopes ventromedially from the edge of dorsal surface and ends in a straight free margin that lies 7 mm. directly above the dorsal surface of the cultriform process of the parasphenoid bone. The space between the postfrontal flange and the cultriform process was occupied by an entirely cartilaginous sphenethmoid bone as no trace of ossification is retained in the area.

Posterior to the postfrontal flange the medial surface of the specimen is badly eroded, containing a number of deep irregular pits (not shown in the figure). Some of these may be, in part, impressions of the outer surfaces of such internal structures as the basisphenoid, epipterygoid, prootic, opisthotic and exoccipital bones. They are, however, so weathered and incomplete that attempts at identification and reconstruction would be speculative at best.

W.A.M. no. 62.1.50 (fig. 3). The impression is from an 8 cm. length of a very slender rostrum anterior to the choanae; an unknown amount of the tip is lacking. It is 3 cm. broad at the posterior end and 1.4 cm. broad at the anterior end. The dentition and other features are hard to trace on the impression but stand out in clear relief on a latex peel.

The anterior borders of the left choana indicates that this opening was oval in shape and slightly broader than the choana of W.A.M. no. 62.1.46. The edge of the right choana is compressed and pushed forward from its original position.

Four rows of small, closely spaced teeth extend forward from the choana to the anterior break on the edge of the fragment. The medial rows are on the vomer bones and border each other on the midline. The lateral rows are on the maxillaries (and, perhaps, in part, on the

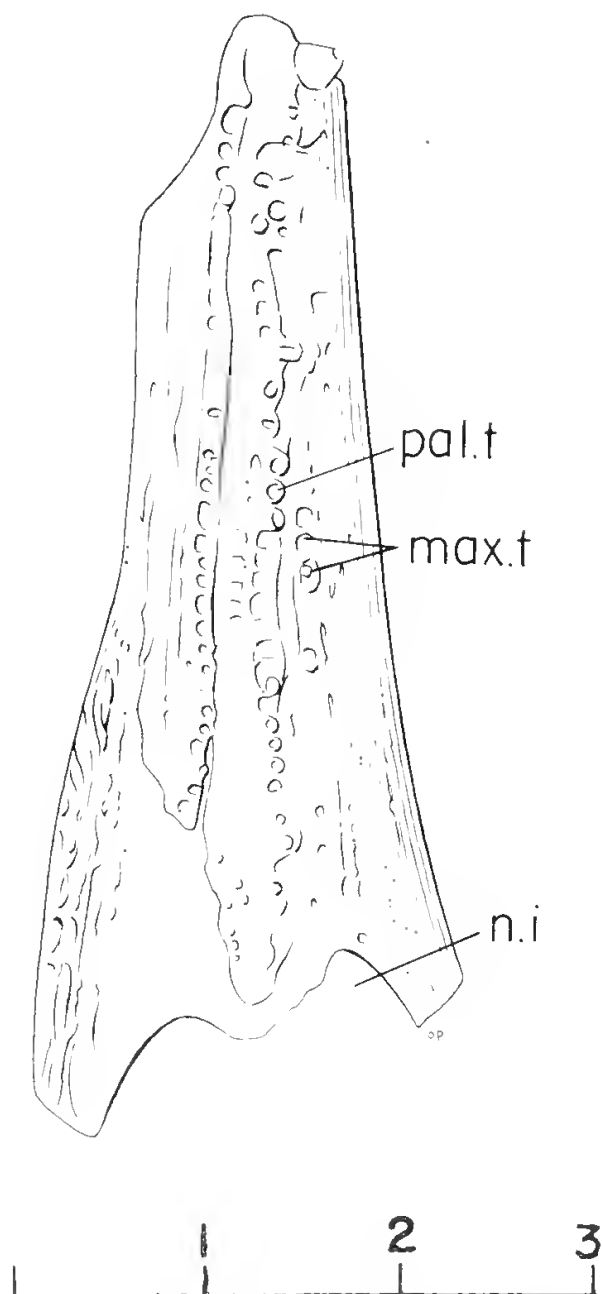


Figure 3.—*Erythrobatrachus noonkanbahensis*, gen. et sp. nov., topotype W.A.M. no. 62.1.50, palatal view of latex peel.

premaxillaries as well), and are separated from the medial rows by narrow fissures. These fissures probably represent the maxillary vomer sutures.

The right posterior part of the maxillary retains an impression of the surface sculpture, a pattern of small, irregular pits.

#### Restorations of the skull

Comparisons among the three skull specimens indicate that they are homotaxial although the two topotypes were clearly derived from individuals considerably smaller than the animal represented by the holotype. Although each specimen comes from a different area of the skull the two topotypes each possess certain features that compliment or coincide with

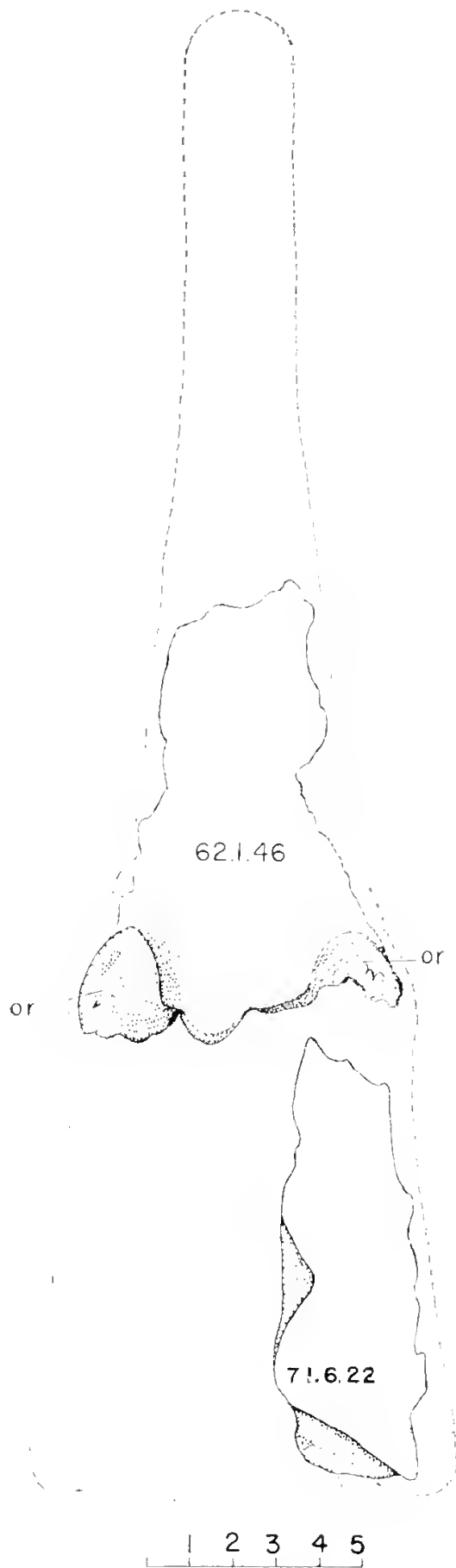


Figure 4.—*Erythrobatrachus noonkanbahensis*, gen. et sp. nov. Restoration of the dorsal surface of the skull, showing the topographical relationships of the two specimens, W.A.M. nos. 62.1.46 and 71.6.22, to each other.

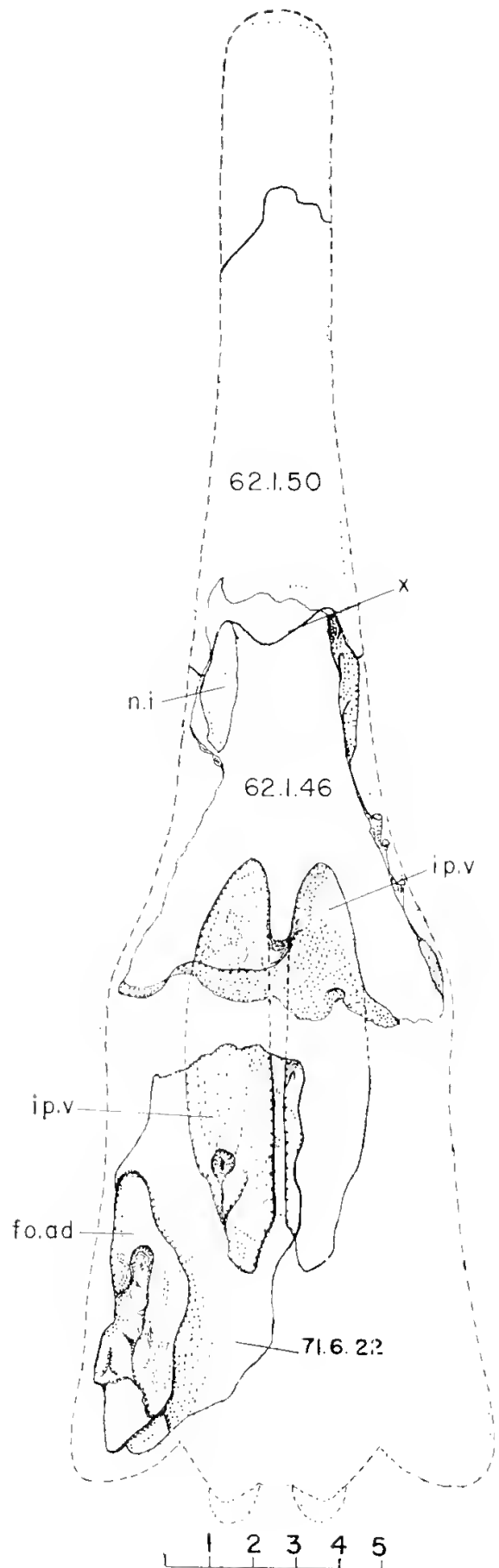


Figure 5.—*Erythrobatrachus noonkanbahensis*, gen. et sp. nov. Restoration of the palatal surface of the skull showing the topographical relationships of the three specimens, W.A.M. nos. 62.1.46, 62.1.50 and 71.6.22, to each other.

features retained by the holotype. Partial restoration of the skull of *Erythrobatrachus noonkanbahensis* are attempted (figs. 4-7) and the results show a long, narrow trematosaurid skull of the *Aphaneramma* type (Säve-Söderbergh, 1936, figs. 31-33).

The basic restorations (figs. 4 and 5) show the topographical relationships of the three specimens to each other in dorsal and palatal view and also the outlines of the original skull as extrapolated from this arrangement of the specimens. In devising these restorations W.A.M. 62.1.46 and W.A.M. 71.6.22 were enlarged X2 to make them comparable in size to the holotype. As shown in the figures there is a slight overlap of portions preserved on W.A.M. 62.1.50 with portions preserved on the holotype but no overlap in preserved portions between the latter and W.A.M. 71.6.22.

The more complete restorations (figs. 6 and 7) are attempts to portray most of the internal cast surface of an individual comparable in size to that represented by the holotype. These show such features as the restored shapes of the orbits, external nares, and also the traces of the sutures of the internal cast surfaces. The restoration of the palate also includes those portions of the maxillary and vomerine tooth rows retained as impressions on W.A.M. 62.1.50.

The features of W.A.M. 62.1.50 that indicate that it is homotaxial with the holotype and that it should be positioned as shown in fig. 5 concern the trends of its lateral margins and the position of its internal nares. As observed on the holotype the rapid convergence of the margins of the cast surface in the region of the internal nares, matched by the angle at which the right internal naris converges on the skull midline, definitely shows that the original complete skull terminated anteriorly in a very long, slender, prenasal rostrum. This anticipated shape for the rostrum is realized closely by the impression surface of W.A.M. 62.1.50. With X2 enlargement of this specimen a nearly exact fit is achieved with the broken anterior edge of the holotype. This fit is further confirmed by the matching of the borders of the internal nares of the two specimens. As noted in the description the anterior margins of both internal nares are present on the W.A.M. 62.1.50 impression. They have been somewhat deflected to the left through postmortem distortion of the specimen but, when restored to their natural positions, the right margin coincides with the anterior margin of the right internal naris of the holotype and the left margin falls near the position the anterior margin of the missing left internal naris of the holotype would have occupied.

The features of W.A.M. 71.6.22 that indicate it is homotaxial with the holotype and that it should be positioned as shown in figs. 5 and 6 concern the relative sizes, positions and shapes of the orbits, interpterygoid vacuities and cultriform processes of the parasphenoid bones. In this topotype a portion of the posterior margin of the right orbit is retained on its anterior break surface. With X2 enlargement it can be

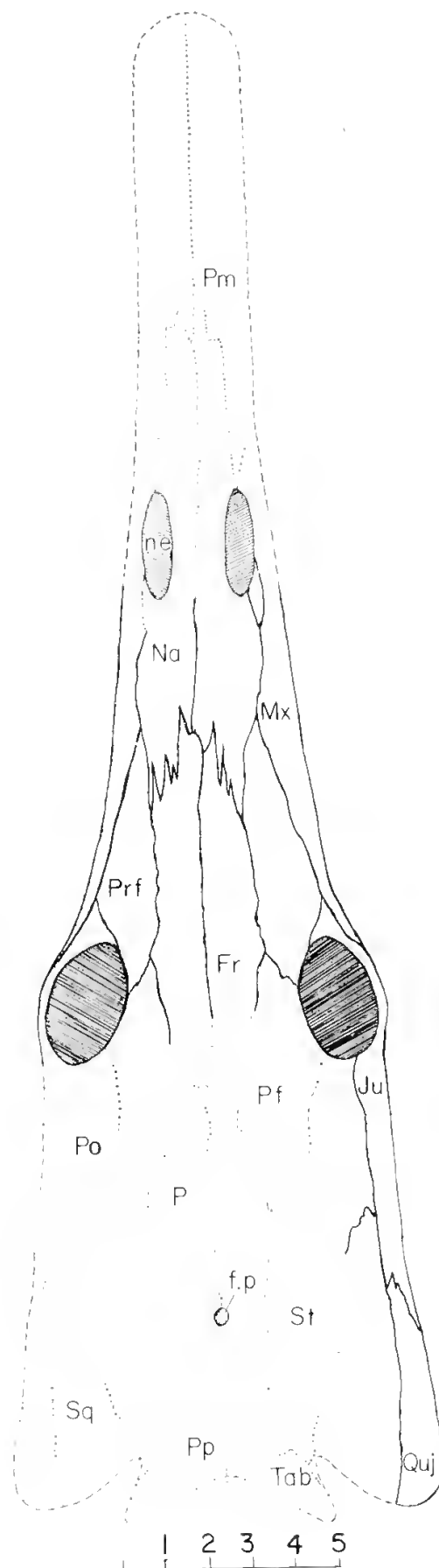


Figure 6.—*Erythrobatrachus noonkanbahensis*, gen. et sp. nov. Restoration of the dorsal surface of the skull, based on the two specimens, W.A.M. nos. 62.1.46 and 71.6.22, and showing the restored outlines of the skull, restored shapes of the orbits and external nares and the traces of sutures on the internal cast surfaces.

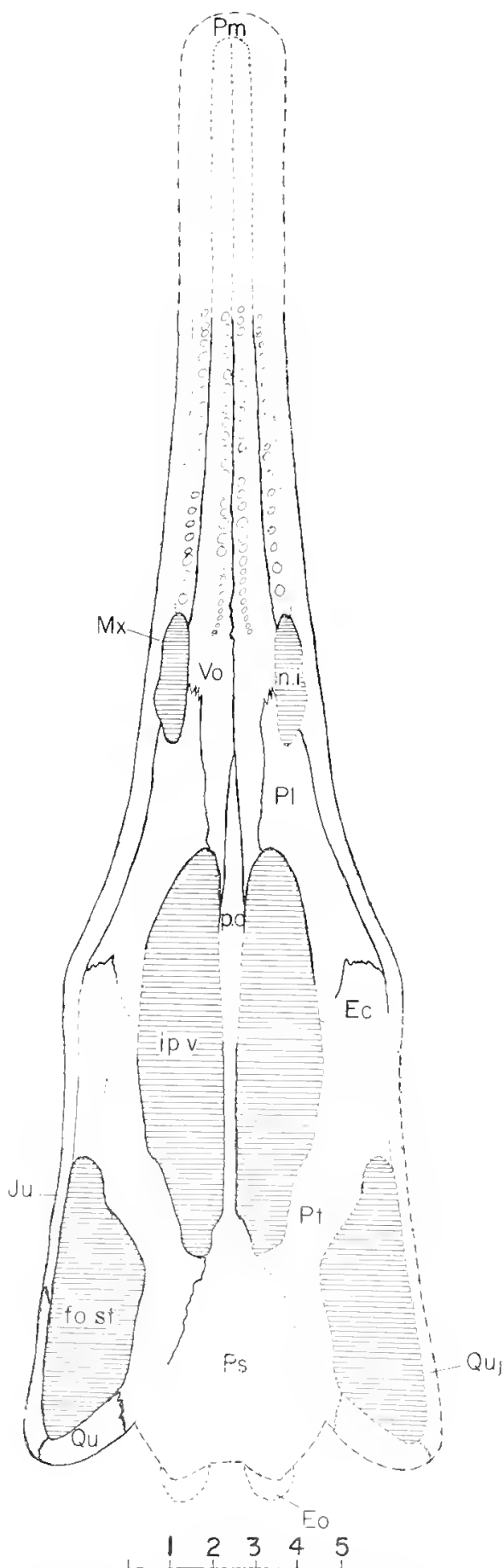


Figure 7.—*Erythrobatrachus noonkanbahensis*, gen. et sp. nov. Restoration of the palatal surface of the skull, based on the three specimens, W.A.M. nos. 62.1.46, 62.1.50 and 71.6.22, and showing the restored outlines of the skull, restored shapes of the subtemporal fossae, interpterygoid vacuities and internal nares. The sutures indicated on the postnasal region are from the internal cast surfaces but the sutures on the prenasal region are the actual external expressions.

seen that this margin represents an orbit comparable in relative size to the orbits represented by their anterior margins on the holotype. The orbits of the two specimens further correspond in that they occupy very lateral positions on the skulls, just internal to the margins of the core surfaces. In similar fashion the posterior part of the right interpterygoid vacuity preserved on the holotype closely resembles the anterior part of the right interpterygoid vacuity preserved on the holotype. As seen in fig. 5 the interpterygoid vacuity portions of the two specimens possess very similar shapes, the one forming a nearly exact mirror image of the other. The medial margins of both are nearly straight and the lateral margins possess the same degree of convexity. Also, the width of this vacuity relative to overall skull width in the orbital region is nearly identical in the two specimens.

W.A.M. 71.6.22 was positioned as shown in figs. 5 and 6 by aligning its cultriform process (which lies in the sagittal axis of the skull) with the cultriform process of the holotype and by placing its posterior orbit margin in such a position as to complete the oval shape of the orbit indicated by the anterior, medial and lateral margins of this opening on the holotype. The lateral margins of the composite restorations of the skull are shown in dashed line. These are drawn to follow the edges of the internal cast pieces with a small amount of extra width added to compensate for missing layers of dermal bone.

The final restoration (figs. 6 and 7) are attempts to summarize all that can be determined of the skeletal anatomy of the skull. They actually represent composite portrayals of the inner and outer surfaces of the dermal bone layer of the skull. Some features such as the outer edges, the margins of the various vacuities and openings and a section of dentition on the palatal surface portray the outer surface of the dermal bone layer. Most of the sutures, on the other hand, are placed according to the trace of their inner surfaces on the core specimens, W.A.M. 62.1.46 and 71.6.22. Regarding some of the more notable features of the skull, their shapes and positions are based on the specimens as follows: orbits, interpterygoid vacuities and cultriform processes on W.A.M. 62.1.46 and 71.6.22; internal nares on W.A.M. 62.1.46 and subtemporal fossae and quadrate regions on W.A.M. 71.6.22. The positions of the external nares are generally established by the fragment of septomaxillary bone impression retained on W.A.M. 62.1.45. They are given the long, oval shape seen in *Aphaneramma* sp. 2. (Säve-Söderbergh, 1936, p.14, fig. 1) and other trematosaurids.

The portions of the skull that are entirely hypothetical, being constructed from linear trends present on the specimens and from conditions in other trematosaurids include the snout tip, the tabular horns, the otic notches, the parietal foramen, the posteromedial portion of the palatal surface in the region of the parasphenoid corpus and the exoccipital condyles.



Almost all of the pattern of sutures shown is included only for aid in visualizing how the entire internal core surface of a skull of the species might have looked. The only sutures included which portray conditions on the outer surface of the dermal bone are the intervomerine and vomer-maxillary in the region anterior to the internal nares. These are taken from palate impression, W.A.M. 62.1.50. The dotted lines lateral to the vomer-maxillary sutures indicate the approximate boundaries between the sculptured bone of the sides of the snout from the smooth, tooth-bearing bone of the palate surface. In regard to all other sutures those that are shown in solid line are definitely established by the specimens and those that are shown in dashed line are either hypothetical or are taken as mirror-images from a definitely established suture on the opposite side of the skull. Not even the definitely established sutures are of use in taxonomic and comparative considerations as it is well known (e.g. Säve-Söderbergh, 1936) that the internal traces of skull sutures differ considerably from their expressions on the outer surfaces of the dermal bone.

#### Comparisons with related species of the Trematosauridae

The narrowness of the skull, the attenuated rostral region and the slender cultriform process of the parasphenoid limit comparisons of the restorations of *Erythrobatrachus noonkanbahensis* (figs. 6 and 7) to two temnospondyl families, the Archegosauridae of the early Permian and the Trematosauridae of the early Triassic. The referral of the new species to the latter family is assured, however, by the construction of the basal region of the palate surface, preserved on W.A.M. no. 71.6.22. In this specimen, as in all trematosaurids and, indeed, all Triassic temnospondyls, the pterygoid bones are solidly fused to the corpus of the parasphenoid through extensive sutural unions. In the archegosaurids, as in many other groups of Permian Temnospondyli, moveable joints are found in this region between the pterygoids and the basisphenoid and the former bones lack sutural union with the parasphenoid.

An additional resemblance to other trematosaurids and contrast of archegosaurids, possessed by *E. noonkanbahensis* concerns the positions of the orbits relative to the interpterygoid vacuities. In W.A.M. no. 62.1.46, as in other trematosaurids, the orbits lie close to the anterior margins of the interpterygoid vacuities. In archegosaurids, however, the orbits overlie the posterior portions of the interpterygoid vacuities.

Possibilities for comparisons of *E. noonkanbahensis* with other trematosaurid species are restricted by the incompleteness and poor preservation of the three specimens comprising its hypodigm. Only a few general characteristics established by the restorations of the skull (figs. 6 and 7) can be utilized in attempting to establish the taxonomic position of the new form. These include, principally, the general shape and proportions of the skull and the relative

sizes, shapes and positions of its larger openings—orbis, external and internal nares, interpterygoid vacuities and subtemporal fossae. Superficial features such as development and topography of the lateral line grooves, texture of sculpture on the skull roof bones and shape, spacing and arrangement of the tooth rows, features often of taxonomic value within temnospondyl families, are either entirely lacking or are too limited in extent of preservation on the three specimens to be of use in determining relationships. The pattern of sutures dividing the dermal bones of the skull are also useless in this endeavor as it is preserved only as internal traces on W.A.M. 62.1.46 and 71.6.22 and is very restricted in extent on W.A.M. no. 62.1.50.

The trematosaurid genera divide roughly into three groups according to general skull shape: 1) those with extremely narrow, elongate skulls and a rostrum that is very extensive in the prenasal region, i.e. *Aphaneramma*, *Gonioglyptus*, *Stochiosaurus* and *Wantzosaurus*; 2) those with moderately elongate skulls and a rostrum that is not extensive in the prenasal region, i.e. *Inflectosaurus*, *Platystega*, *Microposaurus*, *Trematosaurus*, *Trematosuchus* and *Tertrema*; and 3) an isolated genus, *Lyrocephalus*, with a short, nearly triangular skull. A thorough review of the family, beyond the scope of this paper, might conclude by establishing subfamily rank for each of these three groups. Subfamilies corresponding to these groups for the most part were provisionally proposed by Säve-Söderbergh (1935, pp. 85-87 and 200).

It is obvious, without further elaboration, that *E. noonkanbahensis* clearly belongs to the first of the groups. The morphologic evidence available, however, is insufficient for determining its exact phylogenetic position within the group. The few available characters that seem to have taxonomic significance do not conclusively show a closer relationship to any one of the genera *Aphaneramma*, *Gonioglyptus*, *Stochiosaurus* and *Wantzosaurus* than to the others. These characters, all of which are quantitative, are summarized above in the diagnosis of the genus *Erythrobatrachus* and below in Table 1.

The interpterygoid vacuities of *E. noonkanbahensis* are comparatively small relative to the length of the posterior portion of the skull roof. The length of the interpterygoid vacuities as measured on the midline is only about eight-tenths of the length of the skull roof as measured in the midline from the level of the anterior margins of the orbits to the posterior edge. In *Gonioglyptus kokeni* these linear measurements are approximately equal. In *Aphaneramma rostratum* the interpterygoid vacuities are about one-fifth longer than the skull roof linear measurement and in *Wantzosaurus elongatus* the interpterygoid vacuities are two-fifths longer.

The skull of *E. noonkanbahensis* is relatively shorter and broader in the region bounded by the orbits, external nares and skull lateral margins than is the case in *A. rostratum* and *W. elongatus*. In the Australian species the width across the anterior margins of the orbits is

Table 1

Measurements and Indices	<i>Erythrobatrachus noonkanbahensis</i>	<i>Aphaneramma rostratum</i> Säve-Söderbergh 1936, figs. 3t	<i>Wantzosaurus elongatus</i> Lehman, 1961, plates 1b	<i>Gonioglyptus kokeni</i> Huene, 1920, figs. 6 and 7	<i>Stochiosaurus nielsenii</i> Säve-Söderbergh 1935, fig. 55
(A) Length from anterior margins of orbits to posterior edge as measured on the midline	124 mm.	60 mm.	69 mm.	122 mm.	...
(B) Length of Interpterygoid vacuities as measured on the midline	97 mm.	67 mm.	97 mm.	118 mm.	...
(C) Length from posterior borders of external nares to anterior borders of orbits as measured on midline	79 mm.	57 mm.	81 mm.	...	...
(D) Width across anterior margins of the orbits	68 mm.	32 mm.	40 mm.	...	...
(E) Width across posteriolateral skull corners (greatest skull width)	99 mm.	60 mm.	73 mm.	62 mm.	115 mm.
(F) Width across posterior margins of the orbits	79 mm.	44 mm.	58 mm.	34 mm.	59 mm.
B/A	0.78	1.18	1.41	0.97	...
D/C	0.86	0.56	0.49	...	...
F/E	0.80	0.73	0.79	0.55	0.52

between eight- and nine-tenths of the length of the skull roof between orbit anterior margins and external nares posterior margins as measured in the midline. In the Spitzbergen and Madagascar genera the width across orbit anterior margins is only about half the length from orbits to external nares.

One feature that may possibly indicate closer relationship of *E. noonkanbahensis* to *A. rostratum* and *W. elongatus* than to *G. kokeni* and *S. nielsenii* concerns the shape of the postorbital portion of the skull. In the Australian, Spitzbergen and Madagascar species the skull increases relatively little in width from the level of the posterior margins of the orbits back to the posterolateral skull corners. In the species from India and Greenland, however, there is marked flaring in the postorbital region. As shown in Table I the width across the posterior margins of the orbits is between seven- and eight-tenths of the width across the skull corners in the first three but only about half in the last two.

#### Comments on stratigraphic correlation and paleoecology

The three fragments of *Erythrobatrachus noonkanbahensis* derive from the upper 10-15 feet of the Blina Shale exposed at V6044. They were found among scree consisting of ferruginized rubble as well as fresh shale fragments. Overlying the Blina Shale slope and about 15 feet above the level on which the fragments were found is a residual rubble of Erskine sandstone. On top of this rubble and capping the hill are remnants of Warrimbah conglomerate. This is the same sequence of rock units as at the Erskine range where the largest collections of fossil vertebrates were acquired. Rough stratigraphic correlation with the Erskine Range

localities is provided by the fact that these lie within the upper 70 feet of the Blina Shale (McKenzie, 1961).

The only other taxon so far identified among fossil material collected at V6044 is a lower jaw fragment of *Deltasaurus kimberleyensis*, U.C.M.P. no. 62158. Material of this animal is abundant at the Erskine Range localities (Cosgriff, 1965) and its presence at V6055 serves to strengthen the stratigraphic correlation of this locality with the Erskine Range localities indicated by the lithologic sequences.

The presence of a slender-skulled, long-snouted trematosaurid in the upper portion of the Blina Shale is consonant with the assignment of this sequence of deposits to the Otoceratan division of the Seythian Stage, an assignment based on a variety of paleozoologic and paleobotanic evidence (Cosgriff, 1965 and 1969). Presently available information limits the range of this type of trematosaurid to the lower and middle portions of the Seythian. The range extends from *Erythrobatrachus noonkanbahensis* in the upper part of the Blina Shale which is Otoceratan in age to *Aphaneramma rostratum* in the Stieky Keep Formation of Spitzbergen, a unit of Owenitan age (Kummel, 1961). *Stochiosaurus nielsenii* and *Wantzosaurus elongatus* are both Gyronitan in age and, thus, fall in the middle of the range. The former derives from the Wordy Creek Formation of Spitzbergen (Trumpy, 1961) and the latter from the middle portion of the Sakamena Group of Madagascar (see Besaire, 1946 and Lehman, 1961). The stratigraphic positions of these various species relative to each other in Spath's (1935) sequence for the Seythian are shown in table 2. The one trematosaurid of the narrow-skulled, long-snouted group that cannot at present be accurately placed within this sequence is *Gonioglyptus kokeni*



Table 2

Scythian	Stephanitan	
	Columbitan	
	Owenitan	<i>Aphaneramma rostratum</i>
	Flemingitan	
	Gyronitan	<i>Stochiosaurus nielsenii</i> , <i>Wantzosaurus elongatus</i>
	Otoceratid	<i>Erythrobatrachus noonkanbahensis</i>

from the *Prionolobus* beds of the Salt Range, India. Kummel and Teichert (1966) have recently investigated the Permian-Triassic sequence in the Salt Range and reviewed the older literature of the subject. As noted by them (*op. cit.*, p. 304), Noetling (1901) included the Zone of *Prionolobus rotundus* in the Ceratite beds of the Salt Range sequence. In their new categorization of the sequence (*op. cit.*, table I, p. 310) the ceratite beds are placed in the Mittiwali Member of the Mianwali Formation and occupy an approximate mid-Scythian position. Thus, although the beds containing *Gonioglyptus kokeni* have not been formally placed in one of Spath's divisions of the Scythian, they are apparently within the stratigraphic range defined by *Erythrosuchus noonkanbahensis* and *Aphaneramma rostratum*.

The possibility of a faunal facies difference existing between the Blina Shale at V6044 and the unit at the Erskine Range localities is suggested by the fact that *Erythrobatrachus noonkanbahensis* is presently known only from the former and has not been identified among a large quantity of fossil vertebrate material collected from the latter. Although such a difference is not substantiated by any lithologic or other faunal distinctions, the nature of occurrences of species related to *E. noonkanbahensis* in other parts of the world provides a suggestion that this may be the case. *Aphaneramma rostratum*, *Gonioglyptus kokeni*, *Stochiosaurus nielsenii* and *Wantzosaurus elongatus* are all associated with marine invertebrates in the deposits in which they occur. This seems to indicate that they were inhabitants of near-shore fresh-water habitats such as deltas, estuaries or lagoons or that they were, indeed, amphibians adapted to an oceanic environment as Wiman (1916) postulated for the family Trematosauridae as a whole. Perhaps, therefore, the Blina Shale at V6044 was deposited in a more seaward area than the Blina Shale at the Erskine Range.

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of Geology, University of Tasmania and figures  
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### 3.—The taxonomic status of small fossil thylacines (Marsupialia, Thylacinidae) from Western Australia

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With an appendix on statistical methodology by D. R. McNeill†

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Fossil thylacines from the Eucla Division of Western Australia have conspicuously smaller teeth than those of modern *Thylacinus cynocephalus*. With size of teeth the criterion, their taxonomic status is assessed using statistical comparisons that include a test developed by McNeil (see the Appendix). The tests show that for the Eucla Division fossil thylacines, the requirement of the "75 per cent rule" for subspecies is not met at a 95 per cent level of confidence. The Eucla Division fossil thylacines are therefore referred to *Thylacinus cynocephalus*. The re-evaluation of the taxonomic status of fossil thylacines from southwestern Australia, using the same tests, confirms Ride's (1964) conclusion that there is no justification for recognizing these fossils as a new subspecies. However, the heterogeneity of the sample leaves the status of those fossils uncertain. Sexual dimorphism is marked in *Thylacinus* and a statistical method is used to separate some Eucla Division fossil thylacines into presumed males and presumed females.

In the Appendix, McNeill shows that Ride's (1964) method of applying confidence intervals to Mayr's (1969) test for subspecies is invalid. McNeill develops a valid statistical process for testing for subspecies, for both small and large samples.

#### Introduction

During 1966 my husband and I discovered the skeletal remains of eight thylacines (Tasmanian "tigers" or "wolves") in a cave in the Eucla Land Division of Western Australia (Lowry and Lowry, 1967). These, and other fossil vertebrate remains were recovered for the fossil collection of the Geological Survey of Western Australia.

Later examination suggested that the thylacines were very small compared with modern *Thylacinus cynocephalus* from Tasmania, and thus the question arose whether they represented a different species or subspecies. To determine the taxonomic status of specimens from the Eucla Division, I have statistically compared selected dental characters with those of a sample of modern *T. cynocephalus*, and also a sample of fossil thylacines from caves in southwestern Western Australia. Ride (1964) showed that the fossils from southwestern Australia tended to be smaller than *T. cynocephalus*, but he considered them to be conspecific.

During the course of my analysis it appeared that some of the statistical techniques used by Ride (1964) should be re-examined (see the

Appendix), and hence a re-appraisal of the taxonomic status of the southwestern Australian fossils is given here. The analysis led to a consideration of sexual dimorphism in *Thylacinus*, which is discussed at the end of the paper, and a method of determining the sexes in a homogeneous sample is given.

#### The taxonomic assessment of fossil *Thylacinus* samples

##### Previous taxonomic assessment of fossil

##### *Thylacinus*

Only one living species, *Thylacinus cynocephalus* (Harris) from Tasmania, is known. It was common until the beginning of the century, but it is now very rare, possibly extinct. On mainland Australia the genus is represented only by fossils.

Size has been a major criterion in separating the described species. Thus Krefft (1871) described *T. breviceps* from Tasmania as a small species, with larger teeth than *T. cynocephalus*, and Owen (1845) considered *T. spelaeus*, an eastern Australian fossil of the Pleistocene, as simply a larger thylacine than *T. cynocephalus*. Another eastern Australian Pleistocene fossil, *T. rostralis*, was described by De Vis (1894) as also being larger than the living species. The Tertiary fossil *T. potens* Woodburne from Alcoota, central Australia, is even more massive than both *T. spelaeus* and *T. rostralis* (Woodburne, 1967).

Other fossils from mainland Australia are mainly smaller in size than *T. cynocephalus*. The small thylacines from southwestern Australia mentioned above, which Ride (1964) considered conspecific with *T. cynocephalus*, are considered to be of late Quaternary age (Merri-lee, 1968). Apart from the small thylacines recovered by Lowry and Lowry (1967), two further small examples have been recorded from the Eucla Division of Western Australia by Cook (1963) and Partridge (1967), with Partridge's specimen being 3,300 years old. Small fossils have twice been recorded outside Western Australia. A single tooth, 4,000 years old, was found in an excavation in a rock shelter at Fromms Landing, South Australia (Macintosh and Mahoney, 1964), and a small thylacine is known from Lake Manindee, New South Wales (Woodburne, 1967).

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### *Size as a taxonomic criterion in Thylacinus*

Previous workers have mostly used size as a criterion for distinguishing thylacine species, and the present study therefore is limited to a consideration of size. The size of an individual thylacine depends in part on its maturity, a problem avoided by measuring and analysing selected tooth dimensions, assumed to remain constant throughout an individual's life. This choice is important because the individuals in the Eucla Division sample show a great range in maturity. Furthermore, post-cranial remains are relatively scarce in the southwestern Australian sample, and no data on post-cranial remains of modern *T. cynocephalus* were available.

There appear to be certain short-comings in some of the previous analyses of size differences between thylacines from various localities. The species concept of the early taxonomists, even if not classically "typological", did not emphasize interbreeding populations and reproductive isolation, as does the "biological" or "evolutionary" concept prominent today (Mayr, 1969), and a concept of a range of variation within a given species was often neglected. For example, *T. breviceps* was based on a sample of two specimens, and both *T. rostralis* De Vis and *T. breviceps* Krefft were compared with a single specimen of *T. cynocephalus*. As neither De Vis (1894) nor Krefft (1871) identify the specimen, it is not known if the same one was used on both occasions. Not surprisingly the validity of some of the species erected during that period has been questioned. Thus Stephenson (1963) considered that *spelaeus* should lapse into synonymy because he considered the differences in size between *T. spelaeus* and *T. cynocephalus* were negligible. This was demonstrated by Ride (1964), who showed that there was no statistically significant difference between mean values of selected dental characters. The short-comings mentioned above can be reduced by taking large samples and analysing them statistically because "the erection of a taxonomic subspecies, species or genus by inferring the nature and limits of corresponding morphological groups from a series of given specimens is essentially a statistical problem" (Simpson, 1943).

Since natural populations of sexually reproducing animals can be expected to differ from one area to another, it is not enough to simply find statistically significant differences between populations to establish a new species or subspecies (Mayr, 1969). The problem of intra-specific variation is more acute when a time element is introduced. The early workers on *Thylacinus* do not seem to have considered the possibility of intra-specific evolutionary changes involving body size, yet during the Quaternary many mammals have shown fluctuations in size (Hooijer, 1949; Kurtén, 1964, 1965, 1968), including much post-Pleistocene dwarfing. Because a short time is involved, Hooijer and Kurtén believed that the differences between the large Pleistocene forms and some of the smaller modern forms are often no more than subspecific. Thus size as a criterion for distinguishing between species of Quaternary mammals

should be used with caution. The Quaternary fossil thylacines may in fact have represented populations of larger and smaller individuals of a single species, that existed on the mainland at different periods of time. Ride (1964) claimed that differences between the small sized southwestern Australian fossils and *T. cynocephalus* were not great enough to warrant even subspecific recognition, but since the Eucla Division fossils appear to be even smaller, the possibility that they represented a subspecies of *T. cynocephalus*, rather than a new species, is considered.

### *The recognition of subspecies in small samples*

Although the species category has objective reality (Simpson, 1943) the subspecies, like the higher categories, has subjective boundaries (Simpson, 1943; Amadon, 1949; Mayr, 1969). The subspecies category has been defined by Mayr (1969) as "an aggregate of phenotypically similar populations of a species, inhabiting a geographic subdivision of the range of the species, and differing taxonomically from other populations of the species". Where there are clear-cut differences between two such populations, the recognition of subspecies is quite simple, but where their intra-population range of variation overlap, a "75 per cent rule" is often used to determine if enough difference exists to warrant recognition by name (Amadon, 1949). This rule or convention is subject to various interpretations, but it is usually required that 75 per cent of specimens in a sample from the proposed new subspecies must differ from "all" (97 to 99 per cent) specimens from all other previously recognised subspecies (Amadon, 1949; Mayr, 1969). The requirement of the rule is approximately met when 90 per cent (or more) is separable from 90 per cent (or more) of samples of all previously recognised subspecies (Mayr, 1969). It is also easier to calculate percentage separation when overlap is symmetrical.

The statistic Coefficient of Difference (abbreviated to CD) proposed by Mayr (1943) and discussed by Mayr (1969) attempts to show whether the requirement of the 75 per cent rule has been met. It is based on the observation that the degree of overlap of two curves is related to the difference of their mean divided by the sum of their standard deviations. With the aid of a table, CD can be used to show whether two samples are sufficiently separate for the populations they represent to be arbitrarily accorded subspecies status. Mayr (1969) gives a table of values of CD and the corresponding percentage separation. See also Table I in the Appendix by McNeil.

The advantage of CD is its simplicity and ease of calculation, but the statistic assumes that the populations are normally distributed, and that values of sample statistics equal those of population parameters; hence calculated values of CD can at best only give an indication of magnitude of overlap between two curves. In borderline cases, or where these assumptions cannot be made, such as when samples are small, a more accurate test is required.

Different authors require different values of CD to demonstrate subspecific separation, depending on their interpretation of the 75 per cent rule. Thus Mayr (1969) requires a value of at least 1.28, representing a separation of at least 90 per cent from 90 per cent, but others are more stringent, requiring up to 97 per cent separable from 97 per cent (Amadon, 1949), which is indicated by a CD value of 1.9. In his study of *Thylacinus*, Ride (1964) considered an intermediate value for CD of 1.5, representing a separation of about 94 per cent from 94 per cent, as adequate for the recognition of subspecies, but that a more stringent test should apply when samples are small, as were the fossil samples available to him. He therefore modified the statistic Coefficient of Difference as given by Mayr and others (1953) by calculating its 95 per cent confidence interval, and requiring a value of at least 1.5 for the lower limit.

Since this paper is in part a continuation and re-evaluation of Ride's (1964) work on *Thylacinus*, it seemed appropriate to extend his statistical approach to the analysis of the Eucla Division thylacines, and to require a value greater than 1.5 for lower confidence limits, when testing percentage separation of the fossils from *T. cynocephalus*. However, McNeil (see the Appendix) shows that Ride's (1964) modification is invalid, and gives the mathematical development of an accurate statistic to which confidence intervals can be applied. I therefore use this statistic and confidence interval, but follow Ride (1964) by requiring a value greater than 1.5 for the lower confidence limit to indicate adequate separation of samples to warrant subspecies recognition of the populations they represented. The 95 per cent confidence interval applied to the statistic developed by McNeil does not give as wide an interval as the one used by Ride (1964); hence I re-evaluate the taxonomic status of the southwestern Australian fossil thylacines. Also, a few more fossil specimens have been discovered since the publication of Ride's (1964) paper.

#### *The use of normal statistics with samples of Thylacinus.*

*Thylacinus cynocephalus* from Tasmania shows strong sexual dimorphism, with males tending to have larger teeth than females (Ride, 1964). Thus the distribution of dental characters from samples of *T. cynocephalus* tend to be bimodal. I have therefore applied  $\chi^2$  tests to the data from the sample of modern Tasmanian thylacines (the only one large enough for the meaningful use of this test), to check whether frequency distributions depart statistically significantly from normality, thus rendering tests based on this assumption invalid. The  $\chi^2$  probabilities are not significant, except for the length of the upper 2nd molar ( $M^2$ ) and the length of the lower 4th molar ( $M_4$ ). Hence results for these characters are doubtful.

#### **Description of the *Thylacinus* samples.**

##### *The control sample of modern Thylacinus cynocephalus from Tasmania*

Dr. W. D. L. Ride (Director, Western Australian Museum) has kindly made available to me many data (largely unpublished) on modern *T. cynocephalus*. These specimens are now lodged at widely separate institutions (see Ride, 1964), which prevented me from re-measuring them. To test my ability to reproduce Ride's measurements I re-measured those fossils in the Western Australian Museum originally measured by him, and applied a t-test (Simpson and others, 1960) to these paired data. The probability that my measurements and Ride's were the same ranged from greater than 50 per cent to greater than 70 per cent. Tooth dimensions are recorded to 0.1 mm, and since 0.1 mm amounts to only one or two per cent of the dimensions of the tooth measurements, I therefore consider comparisons of Ride's data with mine to be valid. Ride (1964) selected the data he published to exclude measurements from juveniles because some of the characters he used include bone and thus are affected by growth, but since I analyse only dental characters, I have included measurements from juveniles. Hence the values for calculated statistics that Ride (1964) records in his Tables 1 and 2 for the four dental characters I also use ( $M^2$ ,  $M^3$ ,  $M_4$ , and  $P_4$ ), are not precisely the same as the values I record in this paper.

##### *The Eucla Division fossil Thylacinus sample*

All fossil thylacines from the Eucla Division were found on the surface of the floors of caves (see figure 1 for the location of the caves). Cave numbers (e.g. N63 below) are those of the cave registration system of the Australian Speleological Federation. Specimen catalogue numbers like 64.8.1 refer to the fossil collection of the Western Australian Museum, and those like F6358 refer to fossils from the collection of the Geological Survey of Western Australia at present housed in the Western Australian Museum.

##### *(i) From Thylacine Hole (N63)*

Thylacine Hole (31° 42' S; 127° 44' E) is about 100 km west of Eucla, and lies on the Hampton Tableland, a semi-arid region characterised by grassy flats and tree-covered ridges. The cave has been described by Lowry and Lowry (1967) who recovered partial or complete skeletons representing eight different thylacines. One of them, F6364, is a remarkably preserved carcass, from which hair and soft tissue has been dated (NSW 28c) at  $4,650 \pm 153$  years BP (Lowry and Merrilees, 1969; Merrilees, 1970). Five specimens, F6353, F6354, F6355, F6357 and F6358, are nearly complete skeletons that include measureable teeth. One specimen, F6356, does not include teeth, and another, F6360, consists only of the pelvis and part of the vertebral column. Measurements from the carcass F6364 are not included in the statistical sample because they could not be made accurately without damaging the specimen.

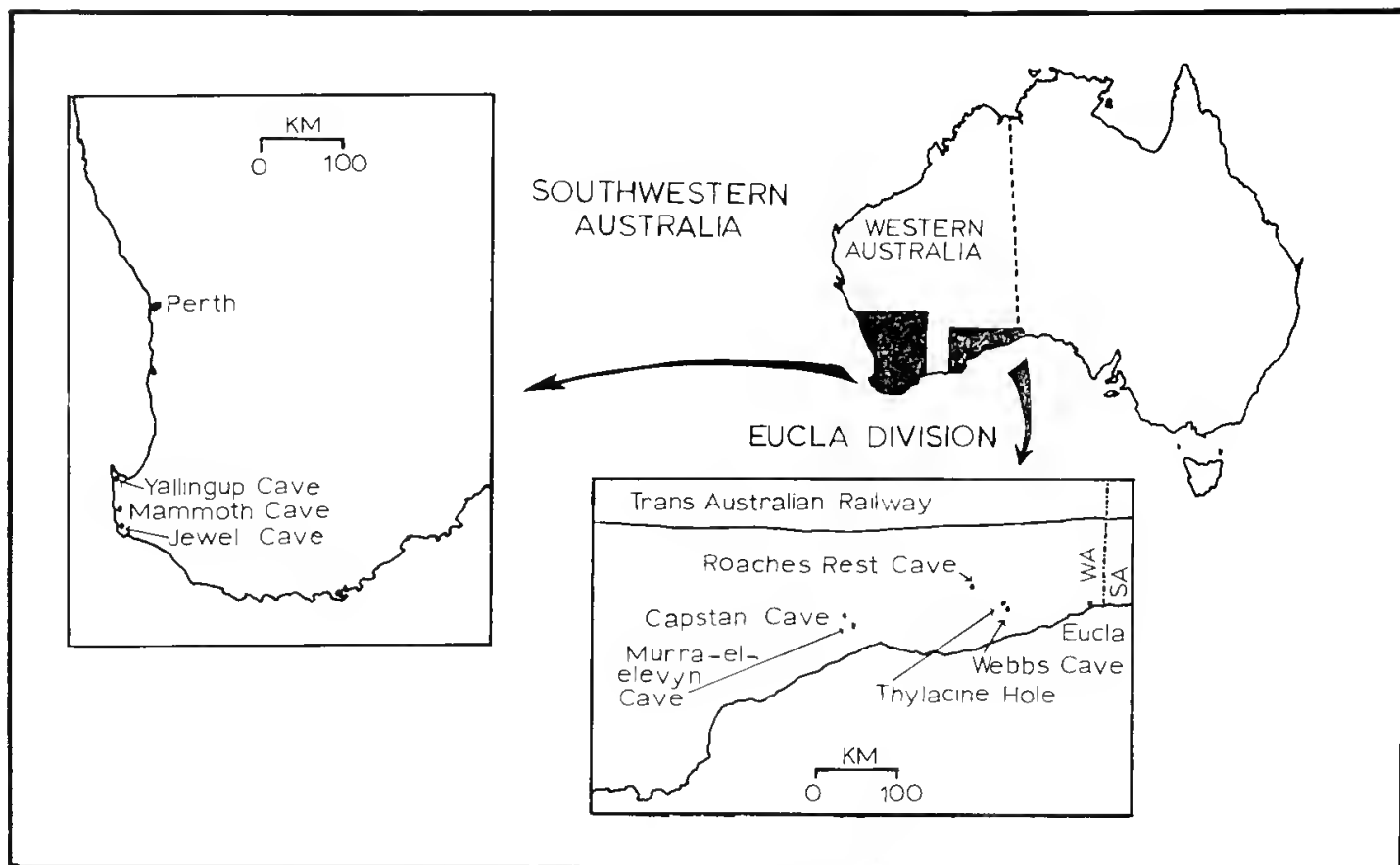


Figure 1.—Locality maps.

The remains represented animals in their death positions, except F6360 which had been disturbed by water wash. All had probably fallen nearly 12 metres through the sole narrow chimney-like entrance into the cave, yet only one specimen, F6355, has broken bones, and even this may have occurred after death through roof collapse of the cave. F6358 is a juvenile with the basioccipital—basipresphenoid and basipresphenoid—presphenoid sutures open, the upper fourth molars not erupted, and no perceptible wear on the teeth. In F6357 both these sutures are fused and the teeth are well worn. The other three specimens show intermediate stages of maturity.

(ii) From Murra-el-elevyn Cave (N47)

Murra-el-elevyn Cave ( $32^{\circ} 03' S$ ;  $126^{\circ} 02' E$ ) is about 6.4 km west of Cocklebidy Motel, on the Hampton Tableland. A single specimen, 64.8.1, with adhering soft tissue dated (GaK 693)  $3,280 \pm 90$  years BP (Partridge, 1967) was recovered from the cave. All teeth are present.

(iii) From Roaches Rest Cave (N58)

Roaches Rest Cave ( $31^{\circ} 33' S$ ;  $127^{\circ} 14' E$ ) is about 45 km northwest of Madura, and lies on the tree-less Nullarbor Plain *sensu stricto*. The single specimen, 67.3.21, represented a juvenile, and consists of fragments of the lower jaw and skull. Some teeth are missing and others are not measurable.

(iv) From Capstan Cave (N50)

Capstan Cave ( $32^{\circ} 01' S$ ;  $125^{\circ} 57' E$ ) is about 14.5 km west of Cocklebidy Motel, on the Nullarbor Plain. The single specimen, 67.11.37, is a right dentary, and carries measurable first and third premolar and first molar teeth.

(v) From Webbs Cave (N132)

Webbs Cave ( $31^{\circ} 46' S$ ;  $127^{\circ} 50' E$ ) lies on the Hampton Tableland, and is near Thylacine Hole, about 90 km west of Eucla. Cook (1963) described a single upper molar, 70.7.54, from this cave. The specimen is mentioned again below, but is not included in my statistical sample because its position in the tooth row is not known with certainty.

*The southwestern Australian fossil Thylacinus sample*

The fossil sample from the southwest of Western Australia includes all specimens measured by Ride (1964, "Western Cave-fossil *Thylacinus*") and those discovered subsequently. Thus the values of calculated statistics I give in Tables 1, 2, and 3 for the dental characters  $M^2$ ,  $M^3$ ,  $M_1$  and  $P_1$  are not precisely the same as those recorded by Ride (1964). Most of the specimens came from caves formed in Quaternary eolianite in the extreme southwestern portion of Western Australia (Figure 1), such as Yallingup Cave (Ya 1), Mammoth Cave (Wi 38-39), and Jewel Cave (Au 13). Two specimens, 61.2.19-23 and 63.7.7, came from caves about 100 km north of Perth. Three of the specimens from the extreme southwest, 61.2.26, 61.2.27, and 61.2.28, came from Mammoth Cave, from a deposit which appears to be more than 37,000 years old (Lundelius, 1960; Merrilees, 1968). Merrilees (1968) considers these to be the oldest specimens available from Western Australia, but that even these are unlikely to be older than late Quaternary.



# Statistical assessment of Western Australian fossil *Thylacinus*

## Results and discussion of statistical tests

The statistical procedure I use to determine the taxonomic status of the fossil samples is similar to the one advocated by Ride (1964, Appendix). After applying  $\chi^2$  tests to check the normality of the data and F-tests to check that sample variances do not differ significantly, mean dimensions of dental characters are compared using a standard t-test. Those characters that give statistically significant values for t are tested for subspecies separation using the statistic developed by McNeil (see the Appendix). A value greater than 1.5 for the lower confidence limit is required to establish subspecies status.

The following dental characters were measured and tested. I follow Ride (1964) in nomenclature.

- (i) Upper molars 1 to 3 ( $M^1$  to  $M^3$ )—diagonal length through protocone to metacone.
- (ii) Lower molars 1 to 4 ( $M_1$  to  $M_4$ )—length.
- (iii) Lower premolars 1, 3, and 4 ( $P_1$ ,  $P_3$  and  $P_4$ )—length.

Upper molars were measured along the longest diagonal crossing the protocone and metacone, and lower molars and premolars along the greatest length in an approximately antero-posterior direction. For consistency right teeth were chosen where possible, although they tend to be a little larger than teeth from the left side. This difference is not significant however. Of 153 pairs of measurements, the mean value of measurements from the right side is 10.21 mm and from the left side 10.18 mm. Copies of the raw data, together with an explanation of their

meaning and accuracy have been lodged in the libraries of the University of Tasmania, Hobart, and the Western Australian Museum, Perth.

Table 1 gives a summary of the dimensions of the dental characters tested, and shows that teeth from the Eucla Division fossils are generally smaller than those of the southwestern Australian fossils, and conspicuously smaller than those of modern *Thylacinus cynocephalus*. Standard tests of comparison were applied to all the data, despite the questionable normality of the lengths of  $M^2$  and  $M_1$  from the modern *T. cynocephalus* sample. Table 2 shows that results of standard tests applied to data from these two characters follow the same trends as those shown by the other characters, and hence can probably be accepted.

Results of F-tests are given in Table 2, and show that the sample variances generally do not differ between the three thylacine samples, excepting variances for the dimensions of  $P_4$  and  $M_3$  from the southwestern Australian fossils. Since in practice the t-test is a robust test (Simpson and others, 1960) it was also applied to these two characters.

Results of the t-tests are given in Table 2, and show that there is no statistically significant difference between mean dimensions of dental characters of the southwestern Australian and Eucla Division fossils at the one per cent level. All the tests between fossil samples and modern *T. cynocephalus* gave significant results at the one per cent level, except the mean dimension of the length of  $P_1$  of the Eucla Division fossils. It is therefore worth testing whether the requirement of the 75 per cent rule for subspecies is met.

Table 1

Summary of dimensions of dental characters of the *Thylacinus* samples.

Character†	Modern <i>Thylacinus cynocephalus</i>						Southwestern Australian Fossil <i>Thylacinus</i>						Eucla Division Fossil <i>Thylacinus</i>					
	Mean X mm.	Observed Range mm.	n	s mm.	V‡		Mean X mm.	Observed Range mm.	n	s mm.	V‡		Mean X mm.	Observed Range mm.	n	s mm.	V‡	
$M^1$	11.6	10.1-12.7 (2.6)	60	0.61	5.3		10.3	9.5-12.1 (2.6)	12	0.72	7.2		10.2	9.5-11.0 (1.5)	7	0.52	5.3	
$M^2$	15.1	13.6-16.6 (3.0)	61	0.88	5.8		13.0	11.4-15.9 (4.5)	12	1.06	8.4		12.5	11.2-13.2 (2.0)	6	0.72	6.1	
$M^3$	17.8	15.4-20.2 (4.8)	54	1.23	6.9		15.4	13.1-17.7 (4.6)	9	1.25	8.4		14.6	13.7-15.3 (1.6)	6	0.77	5.5	
$P_1$	6.2	5.3-7.0 (1.7)	63	0.42	6.9		5.6	4.9-6.4 (1.5)	9	0.49	9.0		5.9	5.5-6.3 (0.8)	6	0.31	5.6	
$P_3$	9.2	8.1-10.1 (2.0)	64	0.46	5.0		8.1	7.1-9.1 (2.0)	11	0.66	8.4		7.8	7.0-8.3 (1.3)	7	0.50	6.6	
$P_4$	10.8	9.2-11.9 (2.7)	64	0.59	5.4		10.0	8.7-12.1 (3.4)	13	1.05	10.7		9.7	8.9-11.0 (2.1)	6	0.82	8.8	
$M_1$	9.6	8.6-10.6 (2.0)	39	0.57	6.0		8.6	7.5-9.8 (2.3)	13	0.66	7.8		8.3	7.9-9.0 (1.1)	7	0.45	5.6	
$M_2$	11.9	11.0-13.2 (2.2)	41	0.53	4.5		11.2	10.2-12.6 (2.4)	11	0.75	6.8		10.4	9.9-11.2 (1.3)	8	0.48	4.7	
$M_3$	14.1	12.8-15.3 (2.5)	41	0.57	4.1		13.0	11.1-15.0 (3.9)	12	1.18	9.3		12.3	11.5-13.0 (1.5)	7	0.67	5.7	
$M_4$	15.8	13.9-17.2 (3.3)	53	0.92	5.8		14.5	12.8-16.9 (4.1)	12	1.32	9.3		13.5	11.8-14.2 (2.4)	6	0.95	7.3	

† Characters are described in the text on page 23.

‡ Coefficient of Variation corrected for small sample size using a correction developed by Haldane (1955).

Table 2

Results of standard tests of comparison.

Character†	Modern <i>Thylacinus cynocephalus</i> compared with Eucla Division fossil <i>Thylacinus</i>					Modern <i>Thylacinus cynocephalus</i> compared with southwestern Australian <i>Thylacinus</i>					Southwestern Australian fossil <i>Thylacinus</i> compared with Eucla Division fossil <i>Thylacinus</i>				
	F	Variance	t	Mean	p	F	Variance	t	Mean	p	F	Variance	t	Mean	p
M <sup>1</sup>	1.38	<0.2	5.55	<0.001**	<0.001**	1.40	<0.2	6.16	<0.001**	<0.001**	1.93	<0.2	0.35	0.8>x>0.7	
M <sup>2</sup>	1.47	<0.2	7.07	<0.001**	<0.001**	1.46	<0.2	7.34	<0.001**	<0.001**	2.14	<0.2	1.07	0.3>x>0.2	
M <sup>3</sup>	2.55	<0.2	6.20	<0.001**	<0.001**	1.04	<0.2	5.57	<0.001**	<0.001**	2.66	<0.2	1.25	0.3>x>0.2	
P <sup>1</sup>	1.83	<0.2	1.57	0.2>x>0.1	<0.001**	1.34	<0.2	3.43	<0.001**	<0.001**	2.45	<0.2	1.09	0.3>x>0.2	
P <sup>2</sup>	1.18	<0.2	7.32	<0.001**	<0.001**	2.02	0.1>x>0.05	6.96	0.01<x<0.001**		1.75	<0.2	0.79	0.5>x>0.4	
P <sup>3</sup>	1.94	0.2>x>0.1	4.04	<0.001**	<0.001**	3.20	<0.001**	3.66	<0.001**	<0.001**	1.64	<0.2	0.60	0.6>x>0.5	
M <sup>1</sup>	1.61	<0.2	5.65	<0.001**	<0.001**	1.34	<0.2	5.20	<0.001**	<0.001**	2.15	<0.2	1.07	0.3	
M <sup>2</sup>	1.24	<0.2	7.64	<0.001**	<0.001**	1.99	0.2>x>0.1	3.49	<0.001**	<0.001**	2.47	<0.2	2.84	0.02>x>0.01*	
M <sup>3</sup>	1.36	<0.2	7.78	<0.001**	<0.001**	4.26	<0.001**	4.55	<0.001**	<0.001**	3.13	0.2>x>0.1	1.52	0.2>x>0.1	
M <sup>1</sup>	1.07	<0.2	5.84	<0.001**	<0.001**	2.03	0.2>x>0.1	4.11	<0.001**	<0.001**	1.93	<0.2	1.65	0.2>x>0.1	

† Characters are described in the text on page 23.

\* Significant at the 5 per cent level.

\*\* Significant at the 1 per cent level.

Results of the test developed by McNeil (see the Appendix) are given in Table 3, and show that no characters from the south-western Australian fossils achieve a significant value of greater than 1.5. Thus the use of a more accurate statistic, a larger sample, and the consideration of extra characters, does not alter Ride's (1964) conclusion that the southwestern Australian fossils are insufficiently separate from *T. cynocephalus* to warrant the creation of a new subspecies, let alone a new species.

The requirement of the 75 per cent rule is met in two dental characters (M<sup>2</sup> and M<sup>3</sup>) from the Eucla Division fossil thylacines, but none of the lower 95 per cent confidence limits achieve this level of significance. Hence one cannot be sure that 94 per cent of the dimensions of these two characters will be separable from 94 per cent of those from modern *T. cynocephalus* in 95 per cent of all possible samples that might be taken from both populations. Since the data from modern *T. cynocephalus* on the length of M<sup>2</sup> is of questionable normality, the result of the test for this character would have been interpreted with caution, even if the lower confidence limit had achieved a statistically significant value. Accordingly, although the teeth of the Eucla Division fossils are significantly smaller, this is an inadequate reason for separating them from *Thylacinus cynocephalus*.

Although the criterion of mean size indicates that the southwestern Australian fossil thylacines should be referred to *T. cynocephalus*, their status is not clear because of the heterogeneity of the sample. This is demonstrated by a high Coefficient of Variation (V) and also a large observed range of variation (Table 1). The mean dimensions given in Table 1 mask the fact that there are four individual specimens from the southwestern Australian sample with tooth dimensions exceeding the mean values of the modern *T. cynocephalus* sample, and that there are five individual specimens with tooth dimensions below the mean values of the Eucla Division sample. Two of the large specimens came from Mammoth Cave, and thus are probably late Pleistocene in age (see above). Until more specimens that can be dated are found from both the southwest of Western Australia and the Eucla Division, there is no way of deciding between three alternatives:—(1) there were two species, a smaller and a larger in southwestern Australia; (2) the size range illustrates an intra-specific post-Pleistocene trend to size reduction in *Thylacinus* in southwestern Australia, as seen in some other mammals (see above); (3) the southwestern Australian fossil thylacines were simply more variable than other populations.

#### *The taxonomic status of the thylacine tooth from Webb's Cave (N132)*

The Webb's Cave tooth, 70.754, was not included in the Eucla Division statistical sample because the position in the tooth row of an isolated tooth is difficult to determine with certainty, but Cook (1963) is probably correct in calling it a left upper 3rd molar. The tooth has a length of 12.8 mm, which is considerably smaller than the mean dimension of 14.6 mm for upper 3rd molars from the Eucla Division sample, but a t-test gives a probability of just



over 5 per cent that it could have come from the Eucla Division population. I therefore refer this molar, assuming it to be an upper 3rd molar, to the Eucla Division fossil thylacines, and hence to *T. cynocephalus*.

### *Sexual dimorphism in Thylacinus*

Modern *T. cynocephalus*, as mentioned above, shows strong sexual dimorphism. Ride (1964) showed that tooth dimensions of modern thylacines of known sex tend to fall into two groups, with those of males being larger than those of females. Thus where the sex of an individual specimen is unknown, its possible sex could be determined by comparing its tooth dimensions with those from other specimens from the same population.

**Table 3**

*Test for subspecies*

Character†	Southwestern Australian Fossil <i>Thylacinus</i>		Eucla Division Fossil <i>Thylacinus</i>	
	CD	CD <sub>1</sub> *	CD	CD <sub>1</sub> *
M <sup>1</sup> ....	0.97	0.68	1.11	0.74
M <sup>2</sup> ....	1.16	0.85	1.51*	1.10
M <sup>3</sup> ....	1.00	0.67	1.33	0.93
P <sub>1</sub> ....	0.61	0.31	0.33	0.02
P <sub>3</sub> ....	1.14	0.83	1.46	1.07
P <sub>4</sub> ....	0.53	0.30	0.86	0.49
M <sub>1</sub> ....	0.83	0.54	1.16	0.78
M <sub>2</sub> ....	0.59	0.30	1.48	1.07
M <sub>3</sub> ....	0.75	0.45	1.59*	1.16
M <sub>4</sub> ....	0.66	0.38	1.26	0.85

† Characters are described in the text on page 23.

\* Significant result.

**Table 4**

*Determination of sex in fossil Thylacinus from Thylacine Hole*

Specimen Numbers	Ranks*					Score†
	1 (smallest)	2	3	4	5 (largest)	
F6358 ...	5	3	1	...	...	14
F6354 .	4	4	1	...	...	15
F6353 .	...	...	3	5	1	34
F6355 .	...	...	3	4	2	35
F6357 .	1	1	1	3	3	33

\* Rank columns record the frequency with which characters from each specimen were accorded a particular rank.

† Score column records the sum of the products of the ranks and frequencies for each specimen, and is a numerical expression of the visual assessment of its size, relative to the other specimens.

As with modern *T. cynocephalus*, the tooth dimensions of five specimens from Thylacine Hole also tend to fall into two groups, which could represent sexes. The following method considered all ten measured characters simultaneously in establishing the grouping of the fossils. Dimensions of dental characters were ranked from 1 (smallest) to 5 (largest) and the "rank" columns in Table 4 record the frequency with which the dimensions of characters from each specimen were accorded a particular rank. The "score" column in Table 4 records the sum of the products of the ranks and frequencies, for each specimen. For example, F6358 ranked smallest for the dimensions of 5 characters, second smallest for the dimensions of 3 characters and third in size for one character, and has a score of  $5 \times 1 + 3 \times 2 + 1 \times 3 = 14$ . This is a numerical expression of the visual observation that its teeth are the smallest of the five Thylacine Hole fossils. Table 4 records two specimens with small teeth (scores under 20) and three with large teeth (scores over 30). I suggest this grouping represents females and male respectively, from a population that on the whole had smaller teeth than the modern Tasmanian thylacine population.

It is possible to argue that the fossils from Thylacine Hole represented two species, one with smaller teeth than the other, but this seems unlikely because modern *Thylacinus* is known to show strong sexual dimorphism (Ride, 1964), and also, the pattern obtained by ranking the dimensions of their teeth indicates that the ratios of tooth measurements within an individual specimen are similar for each of the specimens. A concept of two sexes in a single species is more consistent with this observation than one of two species that lived in the area.

The best preserved fossil thylacine specimen from Thylacine Hole, F6364, was not included in Table 4 because only a few of its teeth could be measured without damaging the desiccated vibrissae, tongue and lips, but I have "ranked and scored" those measurements available from F6364 with corresponding measurements from the other tooth-bearing Thylacine Hole specimens. Its score groups with the two presumed females, and so the carcass probably represented a female.

The determination of the possible sex of an isolated specimen is more complex because thylacine samples from various places on the Australian mainland all have teeth of different mean dimensions. Thus the suggestion by Partridge (1967), that the specimen from Murra-cl-elevyn Cave, 64.8.1 might have represented a female on the basis of its small teeth when compared with mean values for dental characters from the southwestern Australian fossils, cannot now be supported. Subsequent discoveries have shown that the teeth of all thylacines known from the Eucla Division tend to be smaller than mean values for teeth from the southwestern Australian fossils. Furthermore, the method described above apparently can only be used with specimens from the same local population. When tooth dimensions of 64.8.1 are "ranked and scored" with the five

Thylacine Hole specimens, its score is found to lie exactly between those of the presumed males and females, and thus its sex remains uncertain.

Similarly, the sex of the thylacine represented by 70.7.54, the Webbs Cave tooth (Cook, 1963), cannot be determined with certainty because dimensions of several characters from the one specimen need to be assessed simultaneously during the comparisons. However, assuming that the tooth is an M<sup>3</sup>, it is the smallest I have measured, and hence may have represented a female, as suggested by Cook (1963).

### Acknowledgements

I wish to thank Dr. W. D. L. Ride (Director, Western Australian Museum) for freely making available much original information on modern *T. cynocephalus*; for explaining his measuring procedures; for access to Museum material; and for the use of Museum facilities. Thanks are also due to Dr. D. L. McNeil (Statistics Department, Princeton University) for kindly providing the Appendix, and giving me valuable advice on statistical procedures. Dr. N. A. Goodchild (Institute of Agriculture, University of Western Australia) has also given me statistical advice. I would also like to thank Dr. D. Merrilees (Western Australian Museum), and my husband Mr. D. C. Lowry (Geological Survey of Western Australia) for their kind help and valuable criticism.

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### Appendix: Statistical Methodology for Subspecific Separation of Two Populations

By D. R. McNeil

#### The Coefficient of Difference

Suppose we have two populations of individuals, and  $X$  is a characteristic (such as the height of an individual). Let  $X_1$  and  $X_2$  represent the characteristics for individuals from the first and second population, respectively. Suppose also that  $X_1$  and  $X_2$  are normally distributed random variables, with expectations  $\mu_1$ ,  $\mu_2$  and variances  $\sigma_1^2$ ,  $\sigma_2^2$ , respectively. Put

(1)  $F_i(x)$  = Probability that  $X_i \leq x$ ,  $i = 1, 2$ .

Then  $F_i(x)$  is the probability that the characteristic of an individual chosen at random from population  $i$  will not exceed  $x$ .  $F_i(x)$  is called the cumulative probability distribution of  $X_i$ , and may be written

$$(2) \quad F_i(x) = \int_{-\infty}^x f_i(z) dz, \quad i = 1, 2,$$

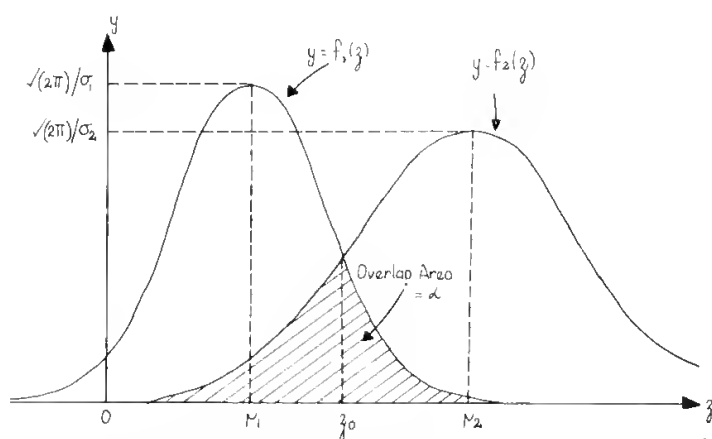
where  $f_i(z)$  is the normal probability density function, i.e.

$$(3) \quad f_i(z) = (2\pi\sigma_i^2)^{-1/2} \exp\left\{-\frac{1}{2}\left(\frac{z - \mu_i}{\sigma_i}\right)^2\right\}, \quad i = 1, 2.$$

The graphs of  $f_1(z)$  and  $f_2(z)$  are depicted in Figure 1.

If one is interested in measuring the difference between the two populations on the basis

of the characteristic  $X$ , a suitable measure must be defined. For definiteness let us assume that  $\mu_2 > \mu_1$ .



Appendix Figure 1.—Curves of the probability densities of the characteristic  $X$ , for the two populations, the variances ( $\sigma_1^2$  and  $\sigma_2^2$ ) being unequal.

One such measure is  $\mu_2 - \mu_1$ , the difference in the expectations of  $X$  for the two populations. Another is the *proportion of overlap* between the two populations, defined as the shaded area in Appendix Figure 1. If  $z_0$  is the point at which the two curves intersect, then the proportion of overlap is obtainable by integration as

$$\alpha = \int_{-\infty}^{z_0} f_2(z) dz + \int_{z_0}^{\infty} f_1(z) dz,$$

$$(4) \quad \alpha = F_2(z_0) + 1 - F_1(z_0).$$

A third measure of the difference between the two populations is the *coefficient of difference*

$$(5) \quad CD = \frac{\mu_2 - \mu_1}{\sigma_1 + \sigma_2},$$

which is commonly used in zoology (see, for example, Mayr, 1969, p. 189).

If the two populations have the same variance, then  $\sigma_1 = \sigma_2 = \sigma$ , say, and, using (3),  $z_0$  is given by the (necessarily unique) point where the curves intersect.

Putting  $f_1(z_0) = f_2(z_0)$  we get

$$(2\pi\sigma^2)^{-1/2} \exp\left\{-\frac{1}{2}\left(\frac{z_0 - \mu_1}{\sigma}\right)^2\right\} \\ = (2\pi\sigma^2)^{-1/2} \exp\left\{-\frac{1}{2}\left(\frac{z_0 - \mu_2}{\sigma}\right)^2\right\}.$$

Solving for  $z_0$  we get  $(z_0 - \mu_1)^2 = (z_0 - \mu_2)^2$ , so that  $z_0 = \frac{1}{2}(\mu_1 + \mu_2)$ . Putting this in (4), we find

$$(6) \quad \alpha = \int_{-\infty}^{\frac{1}{2}(\mu_1 + \mu_2)} (2\pi\sigma^2)^{-1/2} e^{-\frac{1}{2}(z - \mu_2)^2/\sigma^2} dz \\ + 1 - \int_{-\infty}^{\frac{1}{2}(\mu_1 + \mu_2)} (2\pi\sigma^2)^{-1/2} e^{-\frac{1}{2}(z - \mu_1)^2/\sigma^2} dz.$$

The right-hand side of equation (6) may be reduced after some simplification to

$$(7) \quad \alpha = 2\Phi\left(-\frac{\mu_2 - \mu_1}{2\sigma}\right),$$

where  $\Phi(x)$  is the standardized normal cumulative distribution function, i.e.,

$$\Phi(x) = \int_{-\infty}^x (2\pi)^{-1/2} \exp(-\frac{1}{2}z^2) dz.$$

But in the case  $\sigma_1 = \sigma_2 = \sigma$ , the coefficient of difference is, using (5),

$$(8) \quad CD = \frac{\mu_2 - \mu_1}{2\sigma},$$

so that when the variances of the two populations are equal, the proportion of overlap and the coefficient of difference are related by the formula

$$(9) \quad \alpha = 2\Phi(1 - CD).$$

It may be noted that as  $CD$  increases from 0 to  $\infty$ ,  $\alpha$  decreases from 1 to 0. (This can be seen by inspection of Figure 1.) Thus, the larger the value of the coefficient of difference, the smaller the proportion of overlap between the two populations. Some values of  $\alpha$  corresponding to various values of  $CD$  are given in Appendix Table 1. Thus a value of  $CD = 1$  corresponds to a 32% overlap, that is, 16% of the first population are indistinguishable from 16% of the second. A value of  $CD = 2$  corresponds to only 2.3% of the first population being indistinguishable from 2.3% of the second. A discussion of the relationship between  $\alpha$  and  $CD$  is also given by Mayr (1969, p. 190).

#### Description of Ride's Method

In order to determine whether or not two populations are sufficiently different to warrant separate classification, zoologists have suggested that the  $CD$  be used as a measure, but have disagreed on the value required. In practice, it is not possible to measure  $CD$  exactly, since one usually has only a small sample of observations of  $X_1$  and  $X_2$ , and consequently any estimates of  $CD$  will be subject to sampling error. In a situation like this it is customary to obtain a confidence interval for  $CD$ . Such an interval can then be said to contain  $CD$  with a specified degree of certainty (usually 95%). If the interval obtained is wholly above the minimum value

Appendix Table 1

Values of the proportion of overlap,  $\alpha$ , corresponding to the coefficient of difference,  $CD$ .

$CD$	...	...	0.50	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
$\alpha$	...	...	0.62	0.32	0.21	0.13	0.08	0.046	0.024	0.012	0.006	0.002

of CD which is sufficient for separate classification of the populations, then one can say that the populations are separate.

The problem of obtaining a confidence interval for the coefficient of difference has already been considered by Ride (1964), who gives as a 95% confidence interval (CD<sub>1</sub>, CD<sub>2</sub>), where

$$CD_1 = \frac{[\bar{x}_2 - t_2 s_2 n_2^{-1/2}] - [\bar{x}_1 + t_1 s_1 n_1^{-1/2}]}{[(n_1 - 1)^{1/2} s_1 / \chi_{11}^{1/2}] + [(n_2 - 1)^{1/2} s_2 / \chi_{21}^{1/2}]}$$

$$CD_2 = \frac{[\bar{x}_2 + t_2 s_2 n_2^{-1/2}] - [\bar{x}_1 - t_1 s_1 n_1^{-1/2}]}{[(n_1 - 1)^{1/2} s_1 / \chi_{12}^{1/2}] + [(n_2 - 1)^{1/2} s_2 / \chi_{22}^{1/2}]}$$

and:

$\bar{x}_1$  and  $\bar{x}_2$  are the two sample means

$s_1^2$  and  $s_2^2$  are the two sample variances

$n_1$  and  $n_2$  are the sample sizes

$t_1$  and  $t_2$  are the 0.975 quantiles of the Student t-distribution with  $n_1 - 1$  and  $n_2 - 1$  degrees of freedom, respectively

$\chi_{11}^2$  ( $\chi_{12}^2$ ) and  $\chi_{21}^2$  ( $\chi_{22}^2$ ) are the 0.025 (0.975) quantities of the chi-squared distribution with  $n_1 - 1$  and  $n_2 - 1$  degrees of freedom, respectively.

Ride suggests that if both CD<sub>1</sub> and CD<sub>2</sub> are 1.5 or greater the two populations warrant subspecific separation, if neither reaches 1.5 it is probable that the populations are not subspecifically distinct, while if CD<sub>1</sub> is less than 1.5 and CD<sub>2</sub> 1.5 or more further data is necessary to reach a conclusion.

The above procedure is invalid for two reasons:

- (i) Since the higher the value of the coefficient of difference, the more distinct are the two populations, a one sided confidence interval of the form (CD<sub>1</sub>, ∞) is required. In statistical terms, one is testing the null hypothesis

$$H_0: CD < 1.5$$

against the one-sided alternative

$$H_1: CD \geq 1.5,$$

and the larger the value of the calculated coefficient of difference, the greater the evidence in favour of H<sub>1</sub>. In practice, it is not possible to test H<sub>0</sub> against H<sub>1</sub>, since H<sub>0</sub> is not a simple hypothesis (including as it does a whole range of values of CD). Therefore one replaces this range of values by the largest allowable value of CD which is not sufficient to warrant subspecific separation, namely 1.5. We then test

$$H_0: CD = 1.5$$

against

$$H_1: CD > 1.5,$$

and high values of the sample coefficient of difference, i.e. those in an interval of the form (CD<sub>1</sub>, ∞), are significant.

- (ii) In obtaining the upper and lower points CD<sub>2</sub> and CD<sub>1</sub>, Ride has stated that the lower point of the confidence interval for the ratio  $(\mu_2 - \mu_1) / (\sigma_1 + \sigma_2)$  is obtained by combining the lower point for the numerator with the upper point for the denominator (and similarly for the upper point of the confidence interval). This procedure would be valid if  $\bar{x}_2 - \bar{x}_1$  and  $s_1 + s_2$  were perfectly

negatively correlated with each other. To obtain a confidence interval for  $(\mu_2 - \mu_1) / (\sigma_1 + \sigma_2)$  one must obtain the distribution of the ratio  $(\bar{x}_2 - \bar{x}_1) / (s_1 + s_2)$ , considering the joint distribution of  $\bar{x}_2 - \bar{x}_1$  and  $s_1 + s_2$ . As a result, Ride obtains confidence intervals which are much wider than they should be.

We now give a valid statistical procedure for testing for subspecies.

#### Estimation of Coefficient of Difference and Statistical Inference

If  $\sigma_1 \neq \sigma_2$ , it is difficult to relate the CD value to the proportion of overlap. Moreover, unless  $\sigma_1 = \sigma_2$ , it is not possible to obtain exact statistical procedures for making inferences concerning the value of CD. Since in practice it is difficult to reject the hypothesis that  $\sigma_1 = \sigma_2$  (using an F-test based on  $s_1/s_2$ , values vastly different from unity being significant) we will proceed on the basis that the population variances are equal.

Assuming that  $\sigma_1 = \sigma_2$ , and given samples  $(x_{1i}, i = 1, 2, \dots, n_1)$ ,  $(x_{2i}, i = 1, 2, \dots, n_2)$  of  $n_1$  values of  $X_1$  and  $n_2$  values of  $X_2$ , the usual estimator of CD is

$$(10) \quad \hat{CD} = \frac{\bar{x}_2 - \bar{x}_1}{2s},$$

where  $\bar{x}_1$  and  $\bar{x}_2$  are the sample means and  $s$  is the (pooled) sample standard deviation, i.e.

$$s^2 = \{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2\} / (n_1 + n_2 - 2),$$

$$(11) =$$

$$\frac{1}{n_1 + n_2 - 2} \left\{ \sum_{i=1}^{n_1} (x_{1i} - \bar{x}_1)^2 + \sum_{i=1}^{n_2} (x_{2i} - \bar{x}_2)^2 \right\}.$$

Now it follows from (10) after some manipulations, that

$$\hat{CD} - \phi_1 - \alpha \left\{ \frac{n_1 + n_2}{4n_1 n_2} + \frac{(\hat{CD})^2}{2(n_1 + n_2 - 2)} \right\}^{1/2}.$$

$$\frac{\bar{x}_2 - \bar{x}_1 - (\mu_2 - \mu_1)}{(\sigma^2/n_1 + \sigma^2/n_2)^{1/2}} + \left( \frac{4n_1 n_2}{n_1 + n_2} \right)^{1/2} \frac{\mu_2 - \mu_1}{2\sigma} \\ \frac{\{ (n_1 + n_2 - 2) s^2 / \sigma^2 \}^{1/2}}{(12) =$$

$$\frac{1}{\beta} (n_1 + n_2 - 2)^{1/2} \cdot \frac{X + \beta(CD)}{\chi_{n_1 + n_2 - 2}} = \frac{1}{\beta} t\{\beta(CD)\},$$

where  $X$  has a standardized normal distribution,  $\chi^2_{n_1 + n_2 - 2}$  has an independent chi-squared distribution with  $n_1 + n_2 - 2$  degrees of freedom, and  $\beta = \sqrt{\{4n_1 n_2 / (n_1 + n_2)\}}$ . Thus  $\beta \hat{CD}$  has a non-central t-distribution (see, for example, Keeping, 1962, p. 190) with  $n_1 + n_2 - 2$  degrees of freedom and noncentrality parameter  $\beta(CD)$ . Using standard tables of the non-central t-distribution (see, for example, Resnikoff and Lieberman, 1957) one can now obtain a confi-

dence interval for CD. The procedure is as follows.

- (i) Calculate  $\hat{\beta}CD$  from the sample.
- (ii) Determine, from the tables, the value of the non-centrality parameter  $\beta(CD_1)$ , say such that  $\Pr\{t\{\beta(CD_1)\} < \hat{\beta}CD\} = 1 - \alpha$ .
- (iii) The  $(1 - \alpha)\%$  confidence interval for CD is then  $(CD_1, \infty)$ . (If  $\alpha = 0.05$ , a 95% confidence interval will be obtained.)

The procedure is now to accept subspecific classification if  $CD_1$  is greater than 1.5 (say), with  $(1 - \alpha)\%$  certainty of being correct.

#### Large Sample Theory

If  $n_1$  and  $n_2$  are moderately large one can obtain an approximate confidence interval for CD without use of tables. This is based on the

fact that  $\hat{CD}$ , suitably scaled, has a limiting standardized normal distribution as  $n_1$  and  $n_2$  tend to infinity. Using the law of large numbers,  $\bar{x}_2 - \bar{x}_1 \rightarrow \mu_2 - \mu_1$  and  $s \rightarrow \sigma$  as  $n_1$  and  $n_2 \rightarrow \infty$ , so that

$$E[\hat{CD}] \rightarrow \frac{\mu_2 - \mu_1}{2\sigma} = CD$$

as  $n_1, n_2 \rightarrow \infty$ . Similarly it is possible to show that

$$\text{var}[\hat{CD}] \sim \frac{n_1 + n_2}{4n_1 n_2} + \frac{(CD)^2}{2(n_1 + n_2 - 2)},$$

as  $n_1, n_2 \rightarrow \infty$ . Since  $\{\hat{CD} - CD\} / \{\text{var}[\hat{CD}]\}^{1/2}$  is asymptotically standardized normally distributed, an approximate  $(1 - \alpha)\%$  confidence interval for CD is  $(CD_1^*, \infty)$ , where

$$(13) \quad CD_1^* =$$

$$\hat{CD} - \left\{ \frac{(n_1 + n_2 - 2)(n_1 + n_2)}{4n_1 n_2} \right\}^{1/2}$$

and  $\phi_{1-\alpha}$  is the  $1 - \alpha$  quantile of the standardized normal distribution. In particular a 95% confidence interval is given by  $\phi_{0.95} = 1.64$ .

An indication of the exactness of the asymptotic approximation (13) is given by comparing  $CD_1^*$  and  $CD_1$  for moderate values of  $n_1$  and  $n_2$ . These values were checked and found to be in close agreement for the data analysed in Table 1 in the preceding article. For example, for the characteristic  $M_1$ , in the case of the two populations "Modern *Thylacinus cynocephalus*" and "Eucla Division Fossil *Thylacinus*", it was found that at the 95% level  $n_1 = 39$ ,  $n_2 = 7$ ,  $\hat{CD} = 1.16$ ,  $CD_1 = 0.76$ ,  $CD_1^* = 0.78$ .

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## Obituary

### Eric Mervyn Watson 1903-1971

An Honorary Member and former President of the Royal Society of Western Australia, Dr. Eric Mervyn Watson, died at Augusta on September 7th, 1971 at the comparatively early age of 68. In addition to his period of office as President (1943-1944), Dr. Watson was Treasurer of the Society for ten years, and a member of the Council from 1936 to 1952.

Entering the University of Western Australia in 1922 from Perth Modern School, Eric Watson majored in Chemistry, completing his first degree in 1924 and an Honours degree in 1925. He was a student under Professor N. T. M. Wilsmore, and one of many graduates of that era who reached the top levels of the profession. After several positions as an industrial chemist, and temporary lecture-ships at the University of Adelaide and the University of Western Australia, he joined the teaching staff of Perth Technical College in 1929, and spent the remainder of his working life in that institution. Initially appointed an Assistant Lecturer, he rose through the various grades of Lecturer to be head of the Chemistry Department in 1946. During this time he became recognized as an authority on the training of chemists and pharmacists, and was honoured by election to Fellowships of both the Royal Australian Chemical Institute, and the Pharmaceutical Society of Victoria.

In 1930, soon after his appointment at Perth Technical College, Eric Watson was awarded a Hackett Studentship, which enabled him to study at Imperial College in the University of London for a degree of Doctor of Philosophy in the field of organic chemistry. Returning to the College in 1933, he began using the limited research facilities at his disposal to make studies in the chemistry of some Western Australian plants, in particular the eucalypts, and published the results in the Journal of the Royal Society of Western Australia. Although World War II ended this work the knowledge gained was valuable when he became a member of the Western Australian Drug Panel, which was set up to seek alternative sources for a number of pharmaceutical preparations which had been cut off because of hostilities. He was also active in Air Raid Precaution work, lecturing in chemical defence.

From the time he returned from London in 1933, Dr. Watson became increasingly involved in the teaching of Pharmacy students. Pharma-

cology had become a more exact science, and many of the older drugs in the form of plant extracts were being dropped in favour of pure organic chemicals. Pharmacists required a better knowledge of organic chemistry and biochemistry, and Dr. Watson was called on to supply it. He became keenly interested in raising the standard of education in pharmacy, but was also closely involved in establishing various Associateship courses in chemistry at Perth Technical College as qualifications for technologists in industry. In the later years of his career he was responsible for the initial planning of the Chemistry Department at the new Institute of Technology at Bentley.

To the staff of the College who knew him well, Eric Watson was recognized as an outstanding personality. His scholarship, his skill in organising, his ability as a lecturer, and his general capacity for getting things done, earned the respect of all his colleagues. He had little time for educational theorists, and none at all for "red tape" and other administrative tangles.

His students found him a teacher whose material was always well prepared, and whose chemical knowledge was encyclopaedic. He had the reputation of setting a very high standard, but whether or not this was so, at least his students could hold their own in the outside world, and many of them rose to high positions in their professions.

A few years after becoming head of the Chemistry Department Dr. Watson suffered a severe heart attack, and although he made a good recovery, care had to be observed in the years that followed. This involved curtailment of many of his activities, including membership of the Royal Society Council. He sought no further promotion in the College, and retired in 1963 in his 60th year. An active sportsman in his early years, he retained a strong interest in fishing, and spent the last eight years of his life in retirement at Augusta where he could indulge in his hobby. Even then he could not completely drop his active intellectual pursuits, and with his wife was instrumental in setting up a branch of the Western Australian Historical Society at Augusta, of which he was the first President.

The sympathy of all members of the Royal Society go to his widow, Mrs. Rose Watson, and to his son and daughter.



## 4.—The fungus *Panus fasciatus* (Pleurotaceae) characterised by microstructure of sporophore and culture

by Hung Ching Broughton\* and R. N. Hilton\*

Manuscript received 14 December, 1970; accepted 16 November, 1971

### Abstract

The techniques of hyphal analysis and growth on standardised media were used to compare three collections of *Panus fasciatus*, two from Western Australia and the other from New South Wales. Although the sporophores appeared similar macroscopically and microscopically, the cultures from Western Australia differed in growth rate, texture, colour and odour, from those of New South Wales, whilst being similar in their reaction to gallic and tannic acid incorporated in the media and in certain hyphal structures. They are considered to be different varieties of the same species. Another collection from New South Wales, named *Lentinus terrestris* Lloyd, is demonstrably different even at the generic level, although synonymy with *Panus fasciatus* had been suggested.

### Introduction

The taxonomy of the wood-attacking gill fungi, of which *Panus fasciatus* is an example, has been complicated by the ease with which they could be preserved as specimens by the early botanical collectors in various parts of the world. As these collectors did not realise the importance of collecting sporing specimens, and collecting them in sufficient quantity to represent developmental stages and phenotypic variation, numerous taxa have been erected on inadequate material poorly described. The object of the work reported here was to take several collections generally ascribable to *Panus fasciatus* and apply to them full micro-anatomical analysis, that might contribute to their taxonomy, supplementing this with equally exhaustive analysis of cultural characteristics. This combination of sporophore and culture analysis is seen as an essential in the elucidation of wood-attacking fungi (including the polypores) and, as this is the first time these tools have been applied to Western Australian collections, are reported in some detail. No attempt is made to make taxonomic decisions, which will depend on more extensive collections and comparisons with type specimens. However, the features that appear to be important in taxonomy are pointed out and it is shown that *Lentinus terrestris* Lloyd, considered by Cleland (1934 p 171) as probably synonymous with *Panus fasciatus*, must be a separate species on the basis of culture DFP 7396 and its corresponding sporophore.

### Methods

Fresh sporophores were described macroscopically and microscopically, colour descriptions being those of Ridgway (1912). Thin sections of sporophores were mounted in 10% potassium hydroxide containing 1% aqueous phloxine to stain the trama, hymenial layer

and hyphal elements. Melzer's Reagent was used to determine whether spores were amyloid or not.

Cultures were prepared from fresh sporophores and grown on 1.2% Malt Extract Agar as described by Nobles, 1965. Oxidase reactions with gallic and tannic acid were determined by Bavendamm's method as described by Davidson, Campbell and Blaisdell, 1938.

Cultures were examined microscopically after two weeks' incubation in the dark at 25°C, mounts of mycelium being from:—

(1) the advancing zone of the colony, (2) the aerial mycelium at a point one week's growth behind the margin, (3) submerged mycelium below point (2), (4) aerial mycelium at the point of two weeks' growth behind the margin, (5) submerged mycelium at the same point as (4).

Colour descriptions of hyphae and spores were made from water mounts without heat treatment. Mounts for measurements and detailed microscopic analysis were made in 10% potassium hydroxide and 1% phloxine, as used for sporophore material.

### Description of *Panus fasciatus* (Berk.) Pegler from Western Australia

Culture WW1 was isolated from sporophores growing on decayed wood collected in Tutanining Reserve, Western Australia, August 1966 UWA. Mycology Herbarium number 1250. Specimens sent to the Royal Botanic Gardens Kew, were determined by Mr. D. N. Pegler as *P. fasciatus* (Berk.) Pegler, a fungus collected in Tasmania and described by Berkeley as *Lentinus fasciatus* (Pegler, 1965).

Culture XX1 was isolated from an identical fungus collected from a fallen dead trunk of *Eucalyptus marginata*, Karnet, Western Australia, August 1966. UWA Mycology Herbarium number 1260.

### Sporophores

Sporophores tough when fresh, hard when dried. Pilei deeply infundibuliform, densely hispid with involute margins. Clay to Tawny Olive, diameter 1.2–3 cm. Gills deeply decurrent, crowded, entire along the edge, tinged pale purple when fresh but Light Mouse Gray when dried. Stipes, central, 1.0–2.5 cm, densely hispid and brown (Fig. 1).

Pileus with filamentous cuticle and white context. Dimitic; skeletal hyphae mainly in the trama (Fig. 2B) and hyaline, thick-walled, septate, clamped, and occasionally branched, with narrow lumen, 3 — 5  $\mu$  wide, mean  $3 \pm 0.1 \mu$ . In contrast, generative hyphae thin-walled and,

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Figure 1.—*Panus fasciatus* from Western Australia. Sporophores corresponding to culture number XX1.

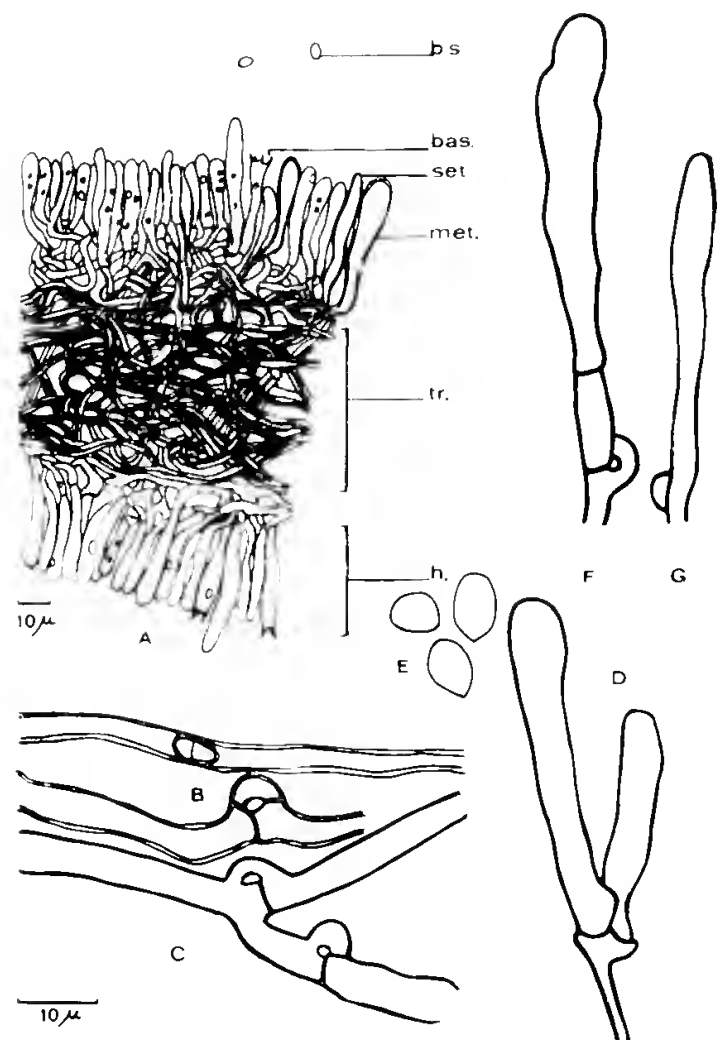


Figure 2.—*Panus fasciatus* from Western Australia. Detail from sporophore corresponding to culture number XX1. A.—Vertical section through gill showing irregular trama (tr) indistinct subhymenium, and a hymenium (h) consisting of clavate basidia (bas.), "metuloids" (met.) and "setae" (set.); basidiospores (b.s.). B.—Skeletal hyphae. C.—Generative hypha. D.—Immature basidia. E.—Basidiospores. F.—Metuloid. G.—Thin-walled "seta".

2—4  $\mu$ , mean  $2 \pm 0.1 \mu$ , and frequently branched (Fig. 2C). Trama irregular and inamyloid, subhymenium indistinct, hymenium of basidia and cystidia (Fig. 2A). Most of the basidia observed in sections were immature (Fig. 2D). Fertile basidia clavate and  $20 - 36 \times 4 - 7 \mu$ , mean  $27 \pm 0.1 \times 6 \pm 0.1 \mu$ . Basidiospores hyaline, inamyloid and oblong, with smooth walls, and  $4 - 7 \times 3 - 5 \mu$ , mean  $5 \pm 0.2 \times 3 \pm 0.1 \mu$  (Fig. 2E). Cystidia originated from tramal hyphae and could be differentiated into two main types. In the first type, the cystidia were few and scattered, had thick walls and obtuse apices. They could be described as metuloids, except for the lack of crystals on their surfaces. They measured  $24 - 43 \times 5 - 7 \mu$  mean  $33 \pm 2 \times 6 \pm 0.2 \mu$  (Fig. 2F). In the second type, the cystidia were similar in size but differed in shape and wall thickness. They were thin-walled, had acute apices and were quite numerous, slightly proliferating above the hymenial surface (Fig. 2G). They resembled setae except for their thinner walls.

#### Cultures: macroscopic

Both isolates had indented margins consisting of appressed and submerged mycelium. The rest of the mycelial mat was raised-woolly with small aggregates of mycelium appearing near and over the inoculum after two to three weeks of growth (Figs. 3, 5). The aggregates grew larger (Figs. 4, 6), and from subsequent development were found to have been fruiting body primordia. Plates were covered after three weeks' incubation. Colour developed after four weeks: Cream Buff, then Pinkish Cinnamon, deepening to Cinnamon Buff after exposure to light. The primordia were of purplish tinge, turning to brown when exposed to light. The reverse side of the mycelial mat changed slightly to Cream Buff, particularly under the intermediate zone and inoculum. Growth rate at  $25^\circ$  was the same in both isolates: 2.0-2.9 cm/wk, mean  $\pm 0.1$ . Reactions on tannic and gallic acid were strong with unsatisfactory growth of both isolates.

#### Cultures: microscopic

All hyphae examined were hyaline with thin walls or with thick refractive walls that stained poorly in phloxine. The advancing zone, aerial mycelium and submerged mycelium shared some hyphae in common. These were either thin-walled hyphae, clamped and occasionally branched (Fig. 7, a1 and a2, e1 and e2), or were wide, conspicuously clamped, with fairly thick, refractive walls characteristically branched from three clamp connections (Fig. 7, d2 and f1).

(1) *Advancing zone* (Fig. 7, a1-d2).—Two principal types of hyphae were found in the advancing zone of both isolates, XX1 and WW1. They were: (i) Long, thin-walled, hyaline hyphae with "eyelet" type of clamp connections, 4-5  $\mu$ , characteristically branched near a clamp connection and forming another clamp near the point of origin of the side branch; occasional in both isolates, (Fig. 1, a1 and a2). (ii) Thin-walled, hyaline hyphae, clamped and frequently branched, branches usually short and produced in close proximity to each other, 2-4  $\mu$  wide; occasional in both isolates (Fig. 7, b1 and b2).

In addition, two more hyphal types were observed in cultures of isolate WW1. These were:— (iii) Long, thin-walled hyphae, clamped, 3-4  $\mu$  wide, with short side branches slightly naviculate in shape; rare, and arranged in a parallel fashion in the advancing zone (Fig. 7, c2). (iv) Large, thin-walled hyphae, 5-6  $\mu$  in diameter, with conspicuous clamp connections and characteristically producing branches from three clamp connections (Fig. 1, d2); rare.

(2) *Aerial mycelium* (Fig. 7, e1-j2).—The aerial mycelium in both isolates, XX1 and WW1, possessed five main types of hyphae, two of which were similar to those in the advancing zone (Fig. 7, e1, e2, f1, f2, compared with a1, a2 and d2). The other hyphal types were:— (i) Long, narrow hyphae with highly refractive walls, bearing small clamp connections and branched, either opposite to a clamp connection or near to a clamp, but more often simple branches were found (Fig. 7, g1-g2). In isolate WW1 only, this type of hypha occasionally was found to produce structures resembling chlamydospores (Fig. 7, h2), but, unlike true chlamydospores, they were not divided from the parent

hypha by a septum near the base. (ii) Narrow, thick-walled hyphae, 1-2  $\mu$  wide, with lumen almost obliterated, frequently branched, resembling fibre hyphae but, unlike them, having small clamp connections, rare in XX1, occasional in WW1 (Fig. 7, i1 and i2). Clamp connections of the "eyelet" type were abundant in cultures of both isolates. Branching of the simple type was frequently found in XX1 but occasionally in WW1, where branching near a clamp connection on the parent hypha and producing another clamp near the origin of the side branch, was slightly more frequent (Fig. 7, j1 and j2). Hyphal diameter 1-5  $\mu$  mean  $3 \pm 0.2 \mu$  for both isolates.

(3) *Submerged mycelium* (Fig. 7, k1-m2).—Hyphae in this area were more intensively branched than in the other areas. Three types were recognised, two of which had been found in the advancing zone and aerial mycelium (Fig. 7, k1, k2 and l1, l2). The third type of hypha was narrow, 1-3  $\mu$  wide, thin-walled and septate, with clamp connections and numerous short side branches often slightly hooked at the tips (Fig. 7, m1 and m2). The

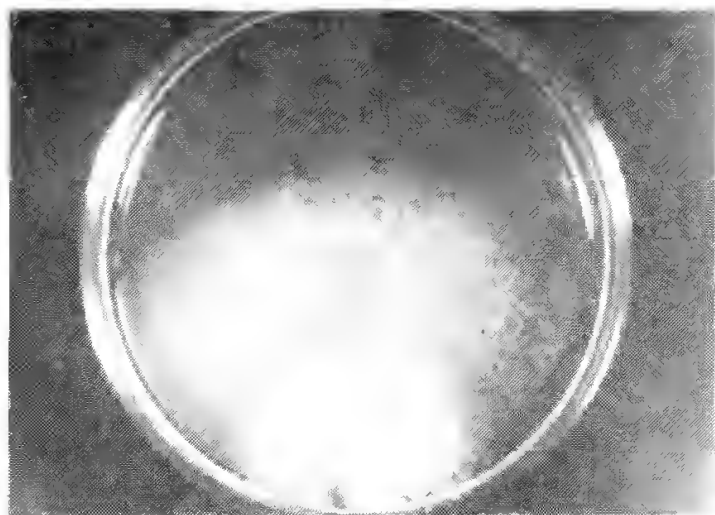


Figure 3 (above).—*Panus fasciatus* from Western Australia. Culture number XX1 two weeks old, showing uneven margin and a raised woolly texture on the mycelial mat. Mycelial mat white.

Figure 4 (below).—*Panus fasciatus* from Western Australia. Culture number XX1 four weeks old, showing that mycelium near and over the inoculum has become very dense. Fruit body primordia have developed near to the inoculum. Mycelial mat now cream buff and pinkish cinnamon.

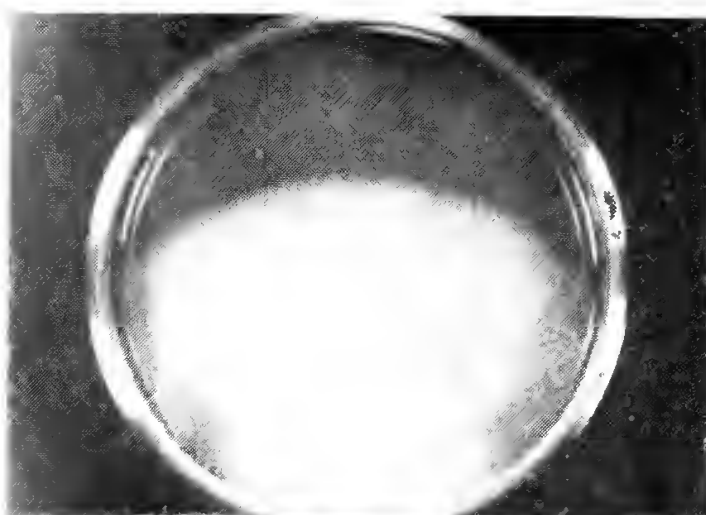


Figure 5 (above).—*Panus fasciatus* from Western Australia. Culture number WW1 two weeks old showing essentially the same features as XX1. (cf Figure 3).

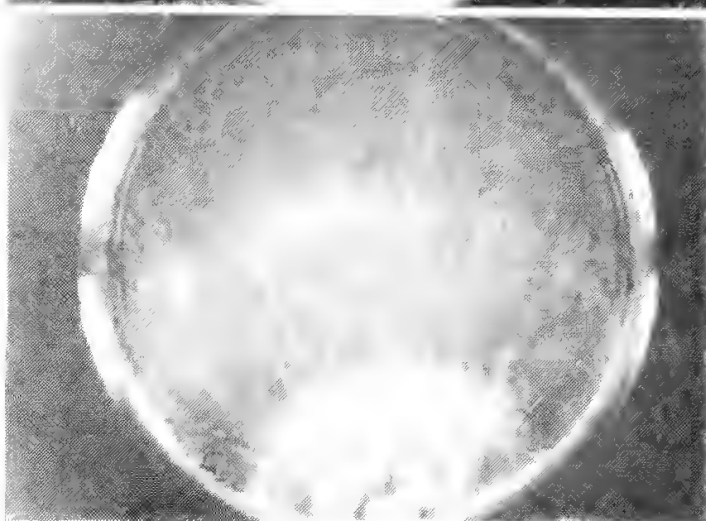


Figure 6 (below).—*Panus fasciatus* from Western Australia. Culture number WW1 after four weeks. Still showing features similar to XX1 (cf. Figure 4).

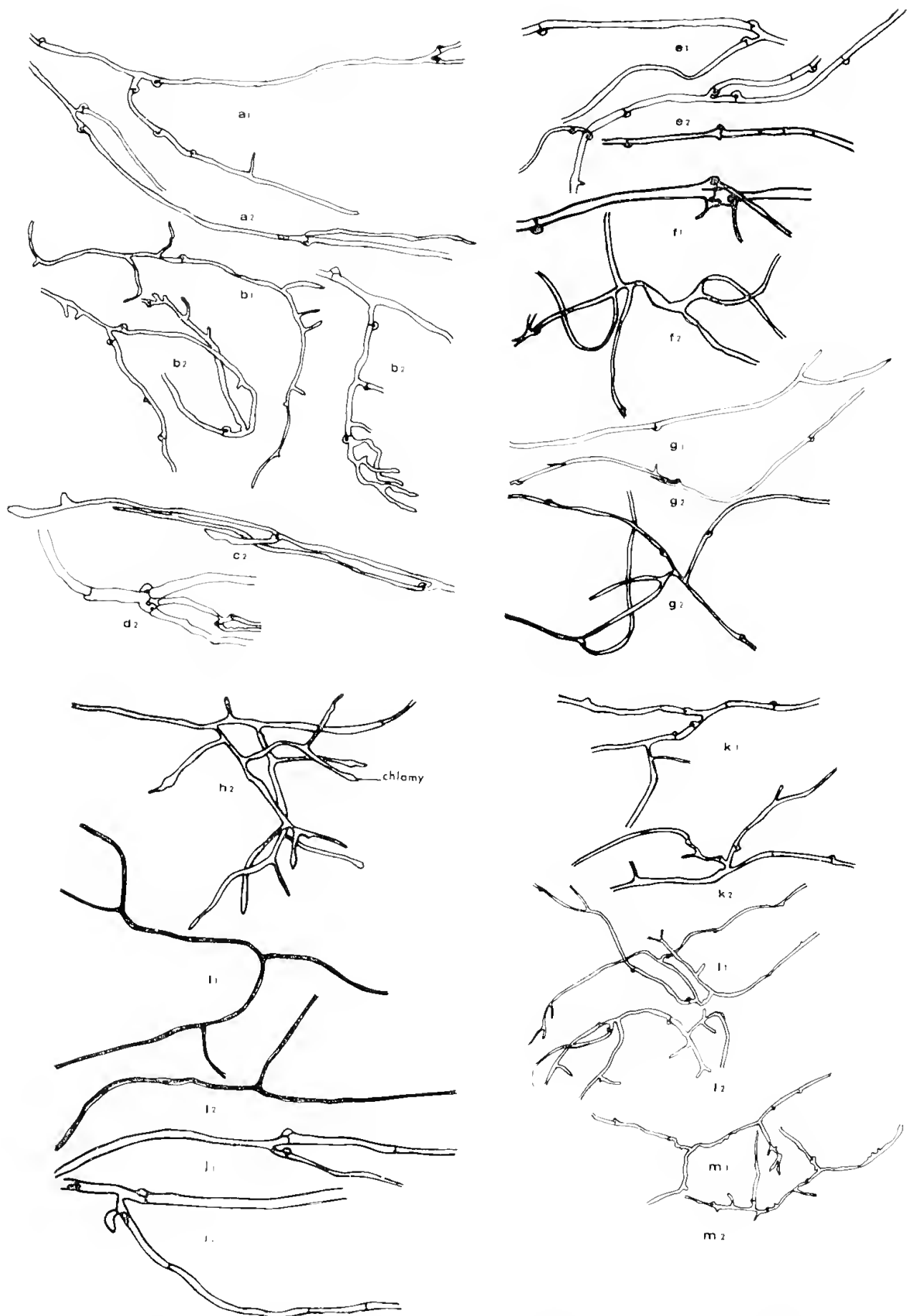


Figure 7. *Panus fasciatus* from Western Australia. Culture numbers XX1 and WW1. Details of hyphae from advancing, aerial, and submerged mycelium. Subscript 1 refers to XX1 and subscript 2 refers to WW1. Advancing zone, a1-d2; b1-b2, hyphae with branches produced in close proximity; c2, hyphae with short side branches slightly naviculate in shape; d2, wide hyphae with conspicuous clamp connections characteristically branched at three clamp connections. Aerial Mycelium, e1-j2; f2, hyphae irregularly enlarged; g1-g2, hyphae with highly refractive walls; h2, hyphae with terminal swellings resembling chlamydospores (chlamy.) except for the absence of a septum; i2, thick-walled "fibre hyphae". Submerged mycelium, k1-m2; m1-m2, hyphae with short lateral branches straight or slightly hooked at the tips.

Table 1

Comparison of sporophore microstructure of *Panus fasciatus* and *Lentinus terrestris*

	<i>P. fasciatus</i> (W.A.)		<i>P. fasciatus</i> (N.S.W.)		<i>L. terrestris</i> (N.S.W.)	
	Range	Mean	Range	Mean	Range	Mean
Basidia	20-36 × 4-7	27 ± 0.1 × 6 ± 0.1	22-54 × 4-7	31 ± 1.8 × 6 ± 0.2	18-40 × 4-9	29 ± 1.2 × 6 ± 0.3
Basidiospores	4-7 × 3-5	5 ± 0.2 × 3 ± 0.1	4-7 × 3-5	6 ± 0.1 × 4 ± 0.1	5-9 × 4-5	6 ± 0.5 × 4 ± 0.2
Skeletal hyphae	3-5	3 ± 0.1	2-5	2 ± 0.2	3-5	4 ± 0.2
Generative hyphae	2-4	2 ± 0.1	2-4	3 ± 0.1	2-4	3 ± 0.1
Metuloids	24-43 × 5-7	33 ± 2.6 ± 0.2	22-36 × 4-7	31 ± 0.7	Nil	Nil

All measurements in  $\mu$ .

"eyelet" type of clamp connection was abundant in the submerged mycelium of both isolates. Hyphal diameter 1-6  $\mu$ , mean  $3 \pm 0.2 \mu$  for both isolates.

#### Comparison of *Panus fasciatus* from Western Australia and New South Wales

Specimens of *Panus fasciatus* from Nambucca Heads, New South Wales, (DFP 5365) showed

strong resemblances to those from Western Australia in the macro- and micro-features of the sporophores. They both had brown, densely hispid, deeply infundibuliform pilei; decurrent gills with entire edges; brown, hispid stipes (Fig. 1 and 8). Microscopically they were similar in having a white context, filamentous cuticle, and an irregular, inamyloid trama consisting of skeletal and generative hyphae. The subhymenium was indistinct in both specimens and the hymenium consisted of essentially the same elements. These were clavate basidia; oblong, hyaline, smooth, basidiospores; metuloids and setae. There was a slight difference in size of these elements between the two specimens (Table 1), and the setae from the New South Wales specimen had thicker walls (Fig. 9, f). Cultures from New South Wales did show differences in texture, colour, odour and growth rate from the Western Australian isolates, although reactions on gallic and tannic acid media



Figure 8.—*Panus fasciatus* from New South Wales. Sporophore corresponding to culture number DFP 5365. Note growth from a pseudosclerotium.

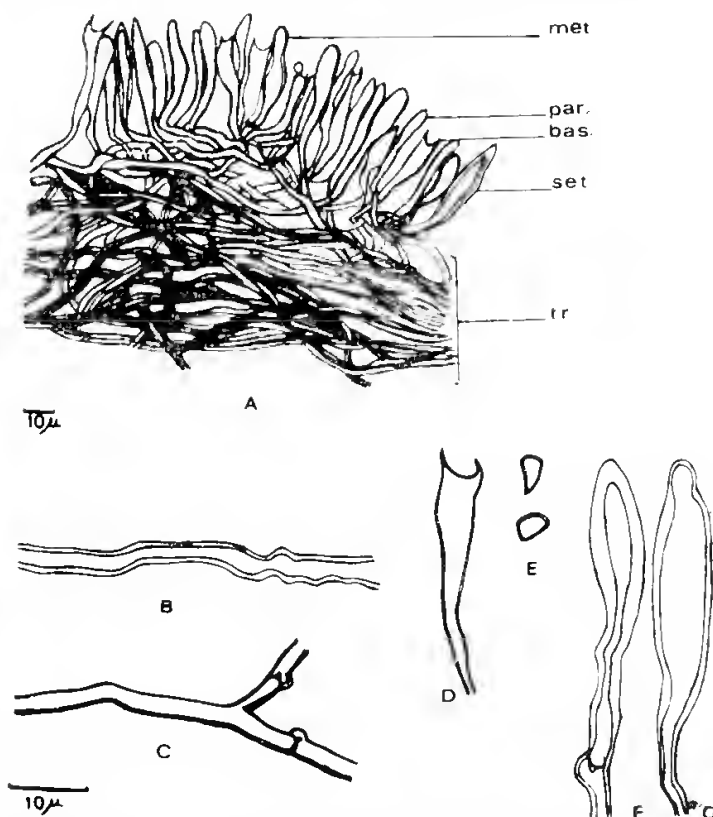


Figure 9.—*Panus fasciatus* from New South Wales. Detail from sporophore corresponding to culture number DFP 5365. A.—Vertical section through gill, showing irregular trama (tr.), basidia (bas.) paraphysate hyphae (par.) metuloids (met.) and setae (set.). B.—Skeletal hypha. C.—Generative hypha. D.—Basidium. E.—Basidiospores. F.—"Seta". G.—"Metuloid".



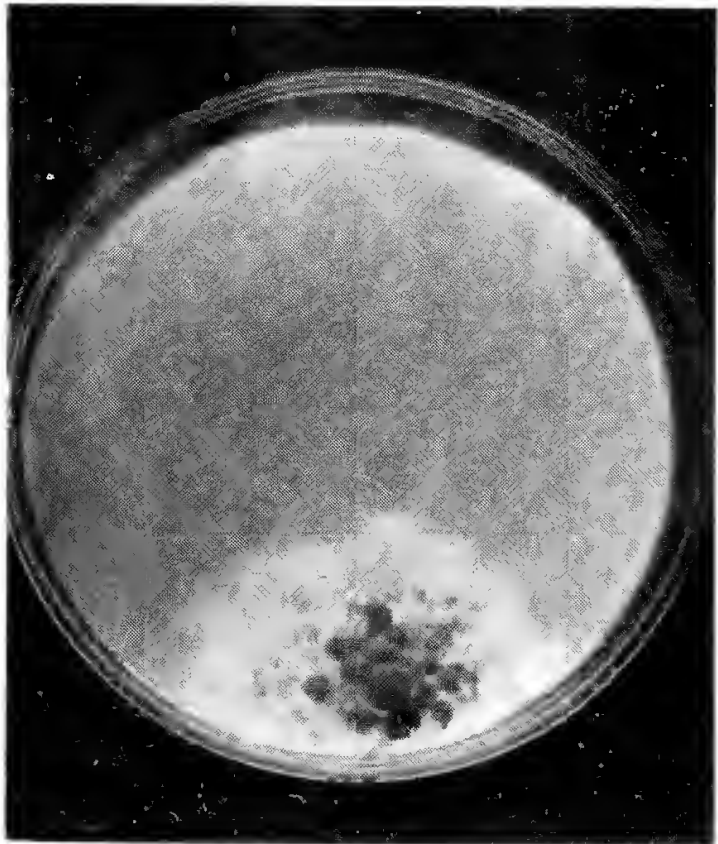


Figure 10 (above).—*Panus fasciatus* from New South Wales. Culture DFP 5365 two weeks old with a raised, silky texture in the younger parts and a sub-felty texture in the older parts of the mycelial mat, which was maize yellow or cream-buff in colour.

Figure 11 (below).—*Panus fasciatus* from New South Wales. Culture DFP 5365 after four weeks, showing little change except for the development of small compact lumps of mycelium over the inoculum.

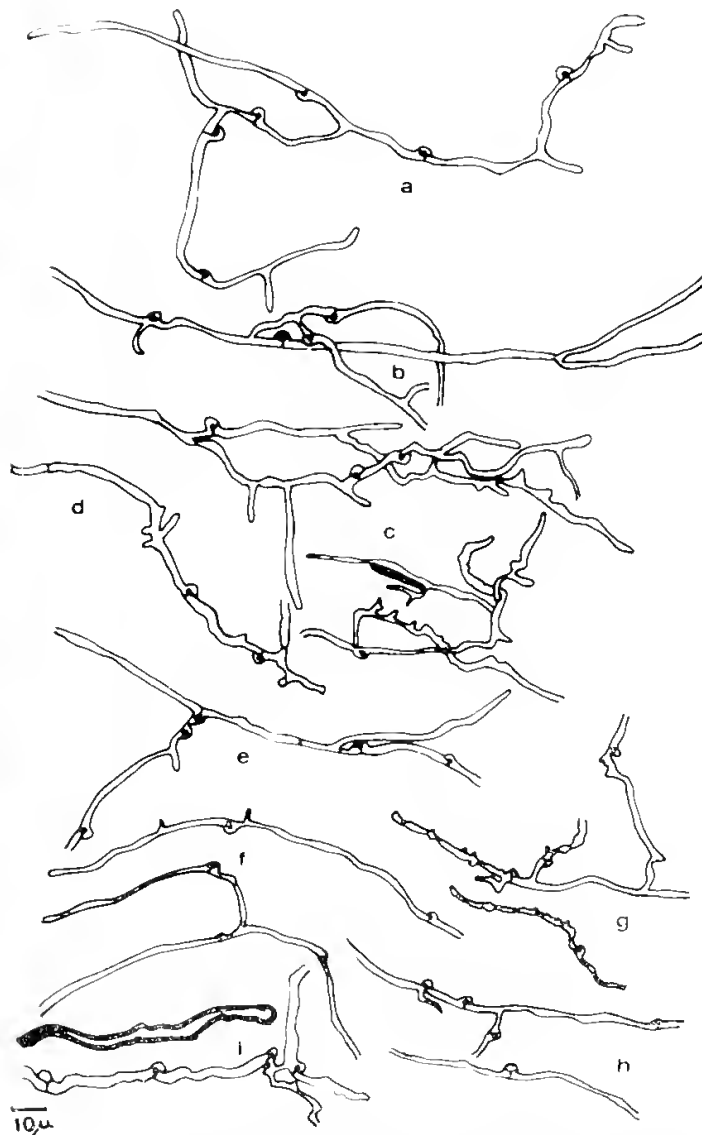


Figure 12.—*Panus fasciatus* from New South Wales. Culture number DFP 5365. a-c, hyphae from the advancing zone; d-f, from the aerial mycelium; g-i, from the submerged mycelium.

were similar. In spite of the differences in the macroscopic appearance of the cultures (Figs. 10 and 11), two hyphal structures were found to be identical between the two isolates (Fig. 12, a, was similar to Fig. 7, a1 and a2, while Fig. 12, c and g resembled Fig. 7, m1 and m2). It can be concluded that the *Panus fasciatus* from New South Wales was the same species as that from Western Australia, but a different variety.

#### Comparison of *Lentinus terrestris* with *Panus fasciatus* from Western Australia

Cleland (1934 p. 171) suggested *Lentinus terrestris* Lloyd (1925) as a probable synonym of *Panus fasciatus* (quoted by him as *L. fasciatus* Fr.). Because of Cleland's suggestion, supported by co-types in his possession, named specimens of *L. terrestris* were obtained from the Division of Forest Products, C.S.I.R.O., Melbourne for comparison with specimens of *Panus fasciatus* from Western Australia. The collection supplied was DFP 7396 collected on Mount Banda Banda, Wauchope, N.S.W., September, 1959.

*Lentinus terrestris* showed differences from *Panus fasciatus* in the macro- and micro-features of the sporophores and in the macro-





Figure 13.—*Lentinus terrestris* Lloyd. Sporophores corresponding to culture number DFP 7396.

scopic and microscopic appearance of the cultures.

Morphologically, *L. terrestris* differed from *P. fasciatus* in having pilei that were slightly depressed at the centres, gills that were dentate instead of entire, and large sporophores that were also hispid but with shorter abhymenial hairs. *L. terrestris* grew from a pseudosclerotium in soil. (Fig. 1 and Fig. 13).

Microscopically (Fig. 14) both sporophores appeared similar but unlike *P. fasciatus*, the trama in *L. terrestris* was subregular (Fig. 14, A), although it was also composed of inamyloid, thick-walled skeletal hyphae. Generative and skeletal hyphae appeared similar in both species and were of similar size (Table 1). The subhymenium was indistinct and the hymenium was composed of essentially the same elements in both species. These were clavate-shaped basidia; hyaline, inamyloid, smooth basidiospores, and setae. However, unlike *P. fasciatus*, *L. terrestris* had no metuloids. Basidia and basidiospores were larger in *L. terrestris* (Table 1) and the setae in *L. terrestris* had uniformly thick walls and were not thin-walled as in *P. fasciatus* from Western Australia.

Cultures of *L. terrestris* (Fig. 15 and 16) differed in texture, colour and growth rate from cultures of *P. fasciatus*. *L. terrestris* had a cottony mycelial mat which became woolly during later periods of incubation. *P. fasciatus* had a woolly texture throughout the whole period of incubation, with the mycelium becoming slightly appressed as the cultures grew older. Growth rate in *L. terrestris* was slower. The mycelial mat was Pale Pinkish Buff, Pinkish Buff or

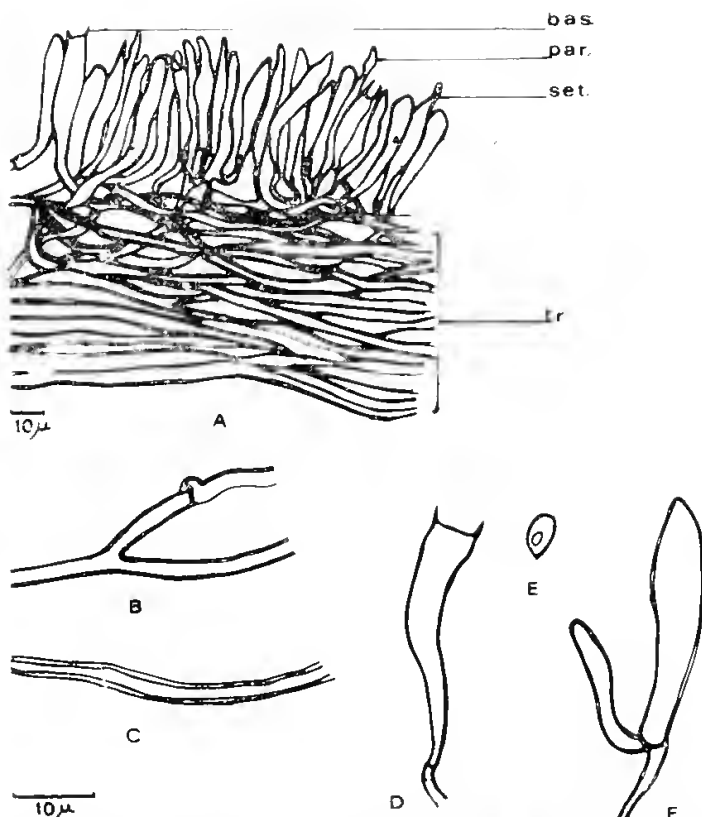


Figure 14.—*Lentinus terrestris* Lloyd. Sporophore corresponding to culture number DFP 7396. A.—Vertical section through gill showed subregular trama (tr.) indistinct subhymenium and hymenium consisting of clavate-shaped basidia (bas.) setae (set.) and paraphysate hyphae (par.) Note absence of metuloids. B.—Generative hypha, thin-walled, clamped and branched similar to those of *P. fasciatus*. C.—Skeletal hypha, thick-walled and rarely branched, resembling those of *P. fasciatus*. D.—Clavate basidium, larger than *P. fasciatus*. E.—Basidiospores similar to those of *P. fasciatus* except for the larger size. F.—Seta, thick-walled.

Light Ochraceous Salmon in *L. terrestris* whereas it was Cream Buff or Pinkish Cinnamon in *P. fasciatus*. Reactions on tannic and gallic acid media differed from *P. fasciatus* only in that on gallic acid being weak.

Microscopically, the hyphae in cultures of *L. terrestris* differed from *P. fasciatus* in the absence of clamp connections (Fig. 17 compared with Fig. 7), the presence of dendritic hyphae (Fig. 17, c) and in having true chlamydospores in the aerial and submerged mycelium in *L. terrestris* (Fig. 17, 1, compare with Fig. 7, h2).

The general characters of the *L. terrestris* isolate, particularly the inamyloid spores and toothed gills, are consistent with its being retained in the genus *Lentinus*, differing from *P. fasciatus* even at this, the generic, level.

#### Acknowledgements

The work described in this paper was conducted during the tenure by Mrs. H. C. Broughton of a University of Western Australia Postgraduate Award. Thanks are due to Mr. E. W. B. DaCosta and Mr. N. E. M. Walters for supplying the New South Wales specimens of *Lentinus terrestris* and *Panus fasciatus* and for helpful discussion during visits to their laboratory in the Division of Forest Products, C.S.I.R.O., Melbourne. Identification of the Western Australian specimen of *Panus fasciatus* from Tutanining was kindly provided by the Royal Botanic Gardens, Kew.

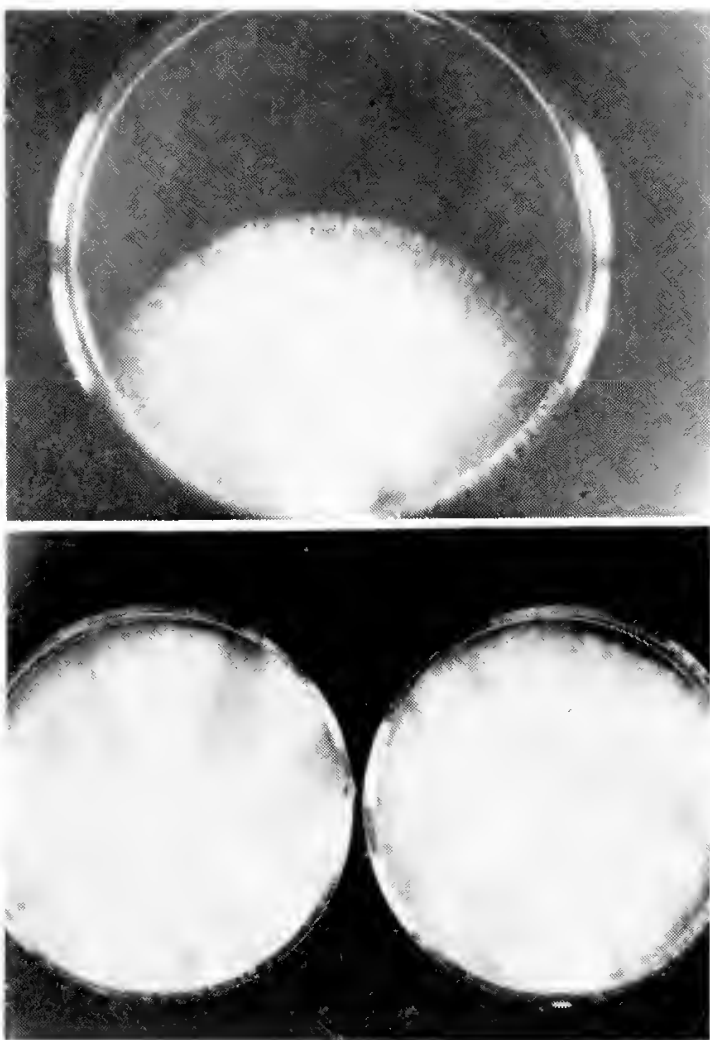


Figure 15 (above).—*Lentinus terrestris* Lloyd. Culture DFP 7396 two weeks old, showing white aerial mycelium, uneven margin and raised cottony-woolly texture.

Figure 16 (below).—*Lentinus terrestris* Lloyd. Culture DFP 7396 four weeks old, showing zones and radial striations on the mycelial mat. Colour developed over the inoculum, but no fruiting bodies even after exposure to light.

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Figure 17.—*Lentinus terrestris* Lloyd. Culture number DFP 7396. a-d, hyphae from the advancing zone; e-h, hyphae from the aerial mycelium; i-k, hyphae from the submerged mycelium; a, hyphae intensively branched; c and f, dendritic hyphae, observed in *L. terrestris* only; d, hyphae with highly refractive walls, and numerous short side branches; m-p, crystals.

## 5.—A new species of the genus *Ramphotyphlops* (Serpentes: Typhlopidae) from Western Australia

by J. Robb\*

Communicated by G. M. Storr

Manuscript received and accepted 22 February 1972

### Abstract

A new species of *Ramphotyphlops* from Western Australia is described, and named *R. leptosoma*. The new species is shown to most closely resemble *R. minimus*, but to be distinguished from it by a number of characters.

### Introduction

In September 1967 Mr. R. B. Humphries collected two specimens of *Ramphotyphlops* at "The Loop", lower Murchison River, Western Australia. The snakes were given to Dr. G. M. Storr of the Western Australian Museum at Perth, who kindly sent them to me for examination. The specimens, one male and one female, proved to be of a previously unrecognised species, and is named and described below.

### *Ramphotyphlops leptosoma* new species

**Holotype:** R 29623 (male); "The Loop", lower Murchison River, Western Australia; 3rd September 1967; collected by Mr. Robert B. Humphries.

**Paratype:** R 29624 (female); same data as holotype.

**Diagnosis:** A small, thin-bodied snake of the genus *Ramphotyphlops* having:

- (1) 16 scale rows at mid-body;
- (2) 650 to 665 dorsal scales;
- (3) prominent snout, with obtusely angular horizontal edge;
- (4) inferior nostrils;
- (5) complete nasal cleft;
- (6) pale coloration throughout with little contrasting darker markings.

**Description of species:** Total length 250 to 282 mm; tail 4.5 times as long as broad in the male, and 2.5 times as long as broad in the female; diameter at mid-body 3.5 mm; dorsal scales (from rostral to terminal spine) 665 in the male, and 660 in the female; spine on tip of tail conical; 16 longitudinal rows of scales at all points posterior to head; four upper labials, first smallest and fourth largest; rostral very large, extending almost to the level of the eyes, rounded posteriorly, the portion visible from below broader than long, almost reaching nostril, concave at mouth edge; eye visible beneath

translucent ocular and preocular scales; preocular narrower than nasal or ocular, partly overlying eye anteriorly, its lower border in contact with second and third upper labials; ocular large, bordered above by supraocular and parietal, and posteriorly by two unmodified body scales, lower edge of ocular in contact with third and fourth upper labials; supraocular and parietal larger than unmodified dorsal scales; frontal smaller than unmodified dorsal scales; nasal divided by nasal cleft into small antero-ventral portion and large postero-dorsal portion; antero-ventral nasal in contact with first and second upper labials; postero-dorsal nasal extending on to top of snout between rostral anteriorly and preocular and supraocular posteriorly, in contact with prefrontal dorsally; nasal cleft extending from lower border of nasal, in contact with second upper labial, through nostril, to meet lateral border of rostral on ventral surface; snout prominent, with obtusely angular horizontal edge, forming a ridge; nostrils inferior; five lower labials, the first and third smallest, fourth and fifth largest.

Colour generally pale throughout, dorsal surface pale grey/brown, undersurface grey/white.

**Range:** Known only from the Murchison River area, Western Australia.

**Relationships:** In characters of bodily scalation and proportions *R. leptosoma* most closely resembles *R. minimus*; these being the only two Australian species so far described with 16 mid-body scale rows, and small, slender bodies. The two are distinguishable from each other on the basis of the shape of the snout (angular in *leptosoma*, blunt in *minimus*); size of the rostral (smaller in *leptosoma* than *minimus*); the disposition of the nasal cleft (which reaches the rostral in *leptosoma* but not in *minimus*), and the colour (fairly uniformly pale in *leptosoma*, while *minimus* has an almost black head and tail or tail only, and yellowish brown body distinctly marked with dark longitudinal lines).

### Acknowledgement

I wish to offer my sincere thanks to Dr. G. M. Storr, of the Western Australian Museum for allowing me the privilege of examining and describing these specimens.

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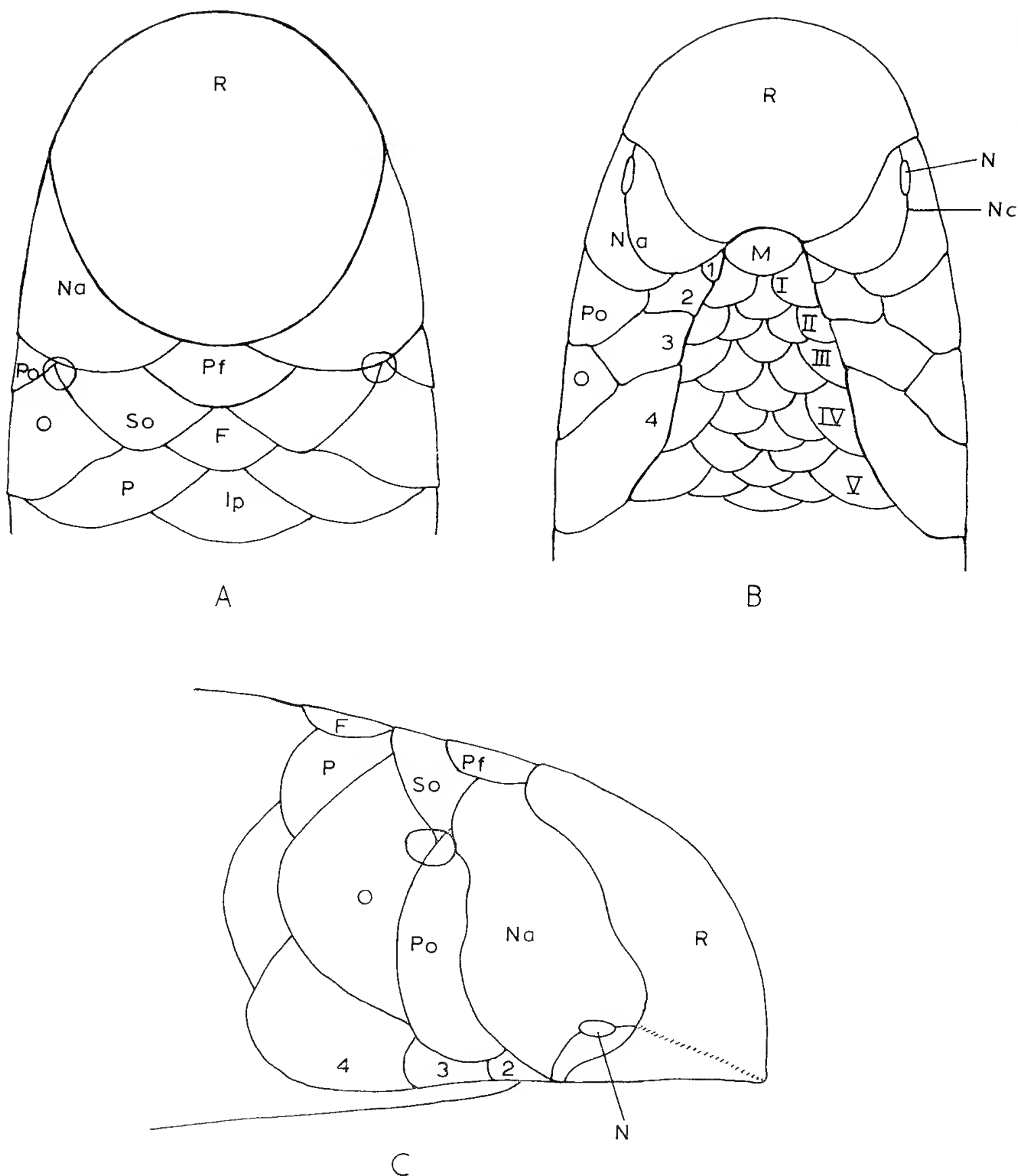


Figure 1.—Head of *Ramphotyphlops leptosoma* new species. A.—Dorsal view. B.—Ventral view. C.—Lateral view. F, frontal; Ip, interparietal; M, mental; N, nostril; Na, nasal; Nc, nasal cleft; O, ocular; P, parietal; Pf, prefrontal; Po, preocular; R, rostral; So, supraocular; 1-4, upper labials; I-V, lower labials.

## 6.—Observations on the Indo-pacific species of *Kraussia* Dana 1852 (Decapoda: Brachyura)

by R. Serene\*

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### Abstract

Ten Indo-pacific species of *Kraussia* are discussed and illustrated, and a key is provided for their identification. Five of the species are new, and described as *K. pelsartensis* and *K. roycei* from Western Australian waters, *K. bongensis* and *K. wilsoni* from the Sulu Sea area, and *K. marquesa* from the Marquesas Islands.

### Introduction

The present observations refer to the study of the collections of *Kraussia* of the Western Australian Museum, and the National Museum of Singapore. Five species, two from Australian waters, one from the Marquesas Islands and two from the Sulu Sea are new. With ten different species in hand an opportunity is provided to review the situation of the Indo-pacific species of *Kraussia* and to suggest a key for their identification. None of the type material of the previously-described species has been examined.

The genus *Kraussia*, with as type species *Kraussia rugulosa* (Krauss 1843), includes in the order of my key the following species: *rugulosa* (Krauss 1843), *quadriceps* Yokoya 1936, *wilsoni* nov. sp., *pelsartensis* nov. sp., *roycei* nov. sp., *?nitida* Stimpson 1858, aff. *nitida*, *marquesa* nov. sp., *rastripes* Muller 1887, *integra* (De Haan 1835), *bongensis* nov. sp.

The species *porcellana* (White 1848) and *proporcellana* Ward 1936 are accepted as synonym of *rugulosa*. I am not sure of the position of *hendersoni* Rathbun 1902 as a valid species, considering the confused situation of *nitida*. The single non west Indo-pacific species of the genus is *K. americana* Garth 1939.

### Specific characters

(1) *Chelipeds*: The key of Balss (1922) mentions as species with reduced fingers only *integra*, and his key of 1938 mentions all species save *rugulosa*. The relative size of the two chelipeds one to another, and the relative size of the palm and the fingers in major and minor chelipeds must be distinguished. Three species, *rugulosa*, *quadriceps*, and *wilsoni* have the two chelipeds of nearly the same size with the palm and fingers somewhat elongate. Five species, *pelsartensis*, *roycei*, *nitida*, *integra*, and *bongensis* have one cheliped clearly larger than the other, the major cheliped having the palm higher and the fingers shorter than the minor. The other two species, *marquesa* and *rastripes*, have the two chelipeds of nearly the same size with high palm and short fingers similar. The shape and proportion of palm and dactylus could slightly vary within

one given species with the size of the specimen, but no sexual dimorphism seems to mark the chelipeds: those of females and males are identical on all species.

The extension on the palm of the black pigment of the fixed finger seems to be a specific character in some cases. On the superior border of the merus, a subdistal spine occurs some distance from the distal margin on nearly all the species; a second, smaller spine generally occurs on the distal margin.

(2) *Measurements*.—Rathbun (1902) gives a specific value to the fronto-orbital breadth in regard to the carapace breadth and the character is used in the key of Balss (1922). Balss (1935) thinks that the proportion of the two breadths can considerably vary on specimens of the same species, but he expresses his views only in regard to the definition of *hendersoni* Rathbun 1902 and with reference to few specimens examined, which in my opinion are perhaps not conspecific.

The breadth of the carapace is mentioned as specific characters in the key of Sakai (1939). Balss (1938) considers also that the proportion of the breadth to the length of the carapace (elongation of the carapace) has a questionable value as a specific character. I have only used this character to separate *roycei* from *pelsartensis*, because it is such a clearly diagnostic feature. However, the views of Balss deserve new consideration. In my key, the measurements are those of the specimens illustrated in the present paper and are in millimetres; the carapace breadth (cb) is the largest.

(3) *Anterior frontal margin*.—To have its full specific value the bilobate character of the frontal margin must be associated with the absence of preorbital teeth and the quadrilobate character to its presence. Among the species with bilobate front, *integra* presents on each lateral lobe a feeble concavity which could be interpreted as feebly quadrilobate when no comparative material is available. In the species with quadrilobate front, the outer lobe is generally a little more protuberant and broader than the inner.

In the present status of our knowledge, it would be unwise to give a specific value to the prominence of the frontal margin in regard to the inner, supra-orbital angle, and to the shape of the frontal lobes. Generally the species clearly differ from one another by those characters (depth and shape of median and submedian sinus, prominence and shape of the frontal lobes). Whether these characters show marked intraspecific variations is still uncertain. A significant example is illustrated by two specimens.

\* Singapore Museum, Singapore.

identified *marquesa*, in the present paper. Further observations could demonstrate that the frontal margin provides a means for specific differentiation.

(4) *Pre-orbital tooth*.—The pre-orbital tooth, which corresponds to a marked inner supra-orbital angle, is separated from the outer frontal margin by the sinus giving passage to the antennal flagellum. When the pre-orbital tooth exists, the antennal flagellum stands out of the orbit; when it does not exist, the flagellum stands in the orbit. Only the three species with bilobate fronts have no pre-orbital tooth. The term "pre-orbital tooth" is used with reference to the previous authors. It would be more appropriate to designate the character by indicating the presence or absence of the antennal sinus between the frontal margin and the inner supra orbital angle; in many cases the term "tooth" being really inadequate. The strong marking or, on the contrary, the disappearance in some cases of the sinus on the outer half of the supra orbital border, also serve for specific differentiation.

(5) *Carapace*.—The distinctly separate, long, acute, forwardly-directed 4 spines on the lateral margin of the carapace behind the extraorbital angle only exists on *rugulosa*. Nearly all the other species have one notch situated at some distance (approximately one-third of the total length of the lateral margin) behind the extra-orbital angle; sometimes this notch is marked posteriorly by a larger spinule of the lateral margin. On some species, *pelsartensis*, *marquesa* and *bongensis*, a second notch (like a small concavity) is situated immediately behind the extra-orbital angle. Other notches can mark the lateral borders, for example, *quadriceps* presents two other feeble notches situated posterior to that corresponding to the anterior third of the lateral border. Sakai (1939) mentions that on *nitida* "one or two shallow indentations occur behind" that of the anterior third. All these structures are more easily observed on the ventral side and probably have a specific value. Comments on their possible function are given at the end of the present paper.

In some species, the dorsal convexity of the carapace is comparatively stronger than in the other species. The ornamentation (granules, setae) of the carapace seem to be specific. However, the rugae on the dorsal surface of *rugulosa* clearly differ from those of other species. The smoothness of the dorsal surface of some species is conspicuous.

(6) *Third maxilliped*.—The ratio of the total length of the third maxilliped to its largest breadth (ischium) is on *rugulosa*: 3.14, *quadriceps*: 2.90, *marquesa*: 2.70, *integra*: 2.60, *rastripes*: 2.57. These discrepancies are not sufficient for specific differentiation but could assist to improve the grouping of the species; the case of the elongate third maxilliped of *rugulosa* is the most significant.

(7) *Pereopods 2-5*.—The upper (anterior) border of the dactyli of pereopods 2-5 on all species tend to be proximally flattened, the two (anterior and posterior) margins of the upper border forming a kind of distinct carinae. Such

a structure varies with the species on pereopods 2-4 and is always more developed on pereopod 5. Only on *rastripes* is it fully developed on pereopods 2-4 which, like pereopod 5, is sharply denticulate along the anterior and posterior margins of the upper border. On the other species, the flattening of the proximal part of dactylus is always (at least on pereopods 3-4) short and the main part of the upper (anterior) margin is like the edge of a blade, generally concave, sometimes sinuous, sometimes straight, sometimes with a row of small denticulations, sometimes smooth. These differences seem to have specific value. Comparison of the dactyli of pereopods 4 and 5 provide an accurate means to separate the species. The posterior margin of the dactyli is always like the edge of a blade and convex. The largest breadth of dactyli in relation to length could also sometimes give a specific discrepancy, but more observations are needed.

(8) *Male pleopod*.—Pleopod 2 is short. Pleopod 1 has been illustrated by Sakai (1934, fig 17a, b) for *integra* and *rugulosa*, Stephensen (1945, fig. 33) for *nitida*, Barnard (1950, fig 36c) and Buitendijk (1960, fig 1b) for *rugulosa*, and Buitendijk (1960, fig 1a) for *integra*.

All the ten species have pleopod 1 with the same elongate and slim stem. However their clear differences from one another in regard to the distribution of subdistal spines and setae and the shape of the apex provide the most secure specific character. The illustrations of pleopod 1 given by previous authors are generally insufficient to allow positive identification.

Several of the specific characters given in the following key and in the illustrations could present intraspecific variations which in some cases are sufficient to mislead identification. More exhaustive observation, taking into consideration the size and sex of the specimens, would probably define other new and secure specific discrepancies. It also will improve the grouping of the species; already *rugulosa* clearly seems to belong to a group quite separate from the other species.

#### Note on the Illustrations

As in many other cases, lack of illustration is the main obstacle to identification of the species of *Kraussia* described and recorded previously. Special care has therefore been taken to illustrate the present material.

The photographs and drawings are made by the author with a Projectina. On the drawings under the largest magnification (x450 on the screen), the lines representing the outlines of each apex correspond to the projection of a selected contour, which varies with the position of the pleopod on the slide. The selection partly reflects the personal interpretation of the author for the shape of the apex; other observations could offer more accurate or different interpretations. The setae of the apex are generally on the ventral side (at least the largest), and their origins are sometimes indicated on the drawings by dotted lines. In any case, the size of the specimen must always be taken into consideration when comparing drawings of pleopod 1.



# Key for the Indo-pacific Species of *Kraussia*

- 1 Lateral border of carapace denticulate with 4 salient separate acute spines behind extraorbital angle. Dorsal surface of carapace with short transverse rugae. Front feebly prominent in regard to pre-orbital teeth which are salient and separated from frontal margin by a deep incision (antennal sinus). Both chelipeds similar subequal with outer surface ornamented with transverse rugae; fingers somewhat elongate (fixed finger a little longer than superior border of palm). Large gaping between fingers which at tip are deeply hollowed. Size: 16.5x19  
*rugulosa*  
(Krauss 1843)
- Lateral border of carapace always more or less regularly denticulate without distinctly longer and more salient spines; generally 1 but sometimes 2-3 notches marked. Dorsal surface of carapace granular or nearly smooth; sometimes granules arranged in short ripple-like transverse rows but not forming clear transverse rugae. Fingers of both chelipeds without hollowed tip ... 2
- 2 (1) Pre-orbital tooth marked. Front quadrilobate ... 3  
Pre-orbital tooth absent. Front bilobate ... 8
- 3 (2) Fingers of cheliped not remarkably shortened. Both chelipeds nearly identically shaped, one being only a little larger than the other. Palm not or very little swollen with outer surface nearly smooth. Cutting edge of fixed finger of cheliped with an elongated subdistal tooth, which is less marked on minor cheliped. Carapace punctate with small granules arranged in feeble and short transverse ripples near frontal and antero-lateral borders  
One cheliped or both chelipeds with remarkably shortened fingers and palm swollen ... 4
- 4 (3) Both chelipeds with palm and fingers similarly elongate; major cheliped a little longer than minor cheliped, but with less high palm. Fixed finger approximately as long as height of palm on minor cheliped, much longer than height of palm on major cheliped. On cutting edge of fixed finger of minor cheliped a well marked elongated subdistal tooth; nearly absent on major cheliped. Black pigment of fixed finger not extending on palm of cheliped. Frontal lobes rounded, deeply separated and strongly prominent beyond preorbital teeth. Dactyli of pereopods 3-4 sickle shaped with anterior border concave. Male pleopod 1 with apex bent laterally and a subdistal bunch of long setae. Size: 17x19  
*quadriceps*  
Yokoya 1936  
Both chelipeds of same length with palm clearly higher and fingers shorter than on *quadriceps*. One cheliped (major) with palm higher and finger shorter than the other (minor). Fixed finger shorter than length of upper border of palm on major cheliped, longer than upper border of palm on minor cheliped. Black pigment of fixed finger a little extending on palm. Frontal lobes not deeply separated and slightly prominent. Dactyli of pereopods 3-4 with anterior border straight. Male pleopod 1 with apex straight truncate without subdistal bunch of long setae. Size: 11x12  
*wilsoni* nov. sp.
- 5 (3) Both chelipeds with palm nearly smooth; upper border of dactyli feebly carinate and granular on proximal part only ... 6  
Both chelipeds with palm ornamented distally with a transverse row of large granules and at least on its distal part smaller granular ripples. Upper border of dactyli strongly carinate and granular ... 7
- 6 (5) Carapace remarkably broad with front-orbital breadth subequal to half breadth of carapace. Frontal margin with widely open median sinus. Major cheliped with strongly swollen palm and short fingers; length of fixed finger much less than half height of palm. Minor cheliped with slim elongate fingers regularly tapering; fixed finger bent downwards with length nearly equal to height of palm. Dactyli of pereopods 2-5 with anterior border nearly straight, flattened and acutely granular at least on proximal half. Apex of male pleopod 1 straight, without subdistal bunch of long setae. Size: 14.6x18.  
*pelsartensis*  
nov. sp.  
Carapace moderately broad with fronto-orbital breadth clearly less than half breadth of carapace. Frontal margin with nearly closed median sinus. Major cheliped with palm feebly swollen and fingers moderately elongate; length of fixed finger clearly more than half height of palm. Minor cheliped as in *pelsartensis* but with fixed finger not bent downwards with strong subdistal tooth on cutting edge; dactylus broader and more canaliculate. Dactyli of pereopods 2-5 with anterior border sinuous without marked flattening and devoided of granules. Apex of male pleopod 1 as a short beak bent at 45° with a subdistal bunch of long setae. Size: 13.2x14  
*roycei* nov. sp.
- 7 (5) Both chelipeds clearly unequal; palm of major cheliped higher than that of minor cheliped; dactyli of at least minor cheliped not remarkably recurved; fixed finger of major cheliped clearly shorter than half height of palm, of minor cheliped clearly longer than half height of palm. No indication of black colour extending on palm. Frontal margin with closed median sinus. A clear sinus on outer part of upper orbital border. Dactyli of pereopods 2-5 sickle shaped without granules on anterior border. Male pleopod with apex bent at 50° and ornamented with a ore-apical bunch of long setae. Size: 9.8x10.8  
aff. *nitida*  
Stimpson 1858  
Both chelipeds subequal; dactyli similarly and remarkably recurved and strongly granular. Fixed finger in one cheliped shorter than in the other; its length approximately one-fourth of height of palm instead of one-third in the other. Black

colour of fixed finger extending on palm. Frontal margin with a V-shaped open median sinus. No trace of sinus on upper orbital border. Anterior border of dactyli of pereopods 2-5 feebly concave (nearly straight) with granules only on pereopod 5. Male pleopod with nearly straight apex and a few subdistal setae. Size: 12.7x14

*marquesa*  
nov. sp.

- 8 (2) Dactyli of pereopods 2-5 with upper (anterior) margin nearly straight, flattened with on each side a row of acute granules. Dorsal surface of carapace nearly smooth, strongly and regularly convex in the middle. Antero-lateral borders of carapace regularly convex, thickly armed with acute granules without indication of any notch. No indication of sinus on upper orbital border. Two chelipeds subequal with short fingers identically shaped. On both chelipeds length of fixed finger approximately one-fourth of height of palm. Male pleopod distally acuminate with a subdistal bunch of long setae. Size: 11.1x12.8

*rastripes*  
Muller 1886

Dactyli of pereopods 2-4 with anterior border concave, flattened and granular only on short proximal part; anterior border of pereopod 2 with a row of some acute granules, those of pereopods 3-4 without granules. Dorsal surface of carapace granular. Antero-lateral borders of carapace with a notch at some distance behind the orbit. Strongly marked sinus on upper orbital border. Two chelipeds slightly but clearly unequal

- 9 (8) Frontal margin feebly undulate; dorsal surface of carapace slightly flattened. Both chelipeds with palm and fingers differently shaped. Major cheliped with palm higher, dactylus more recurved, fixed finger shorter than

on minor cheliped. Length of fixed finger one-fourth of height of palm in major cheliped, one-third of height of palm in minor cheliped; black colour of fixed finger not extending on upper half of palm. Male pleopod with apex acuminate. Size: 16x19.5

*integra*  
De Haan 1835

Frontal margin straight; dorsal surface of carapace regularly convex. Both chelipeds with palm and fingers identically shaped; length of fixed finger one-fourth of height of palm; black colour of fixed finger extending on upper half of palm. Male pleopod with apex broadened as a round lobe. Size: 20x23

*bongensi*  
nov. sp.

### *Kraussia rugulosa* (Krauss 1843)

(Figs. 1, 2, 23A)

*Platyonichus rugulosa*, Krauss, 1843, p. 26, pl.1, fig. 5.

*Trichocera porcellana*, White, 1848, p. 59.

*Kraussia rugulosa*, Dana, 1852, p. 302, pl. 9, fig. 1.—De Man, 1887, p. 343, pl. 14, fig. 2.—Borradaile, 1903, p. 270.—Rathbun, 1906, p. 876 (no material).—Stebbing 1910, p. 310.—1918, p. 54.—Balss, 1922, p. 98.—1938, p. 27, fig. 10.—Urita, 1926, p. 11.—Edmondson, 1925, p. 36.—1946, p. 284, fig. 175.—Sakai, 1934, p. 305, text-figure, 76b—1936, p. 139, text-fig. 65.—1939, p. 431, text-fig. 21.—Tweedie, 1947, p. 28.—1950, p. 108.—Barnard, 1950, p. 195, fig. 36A, B. C.—Buitendijk, 1960, p. 253, fig. 1b.

*Kraussia proporciana*, Ward, 1935, p. 10, pl. 1, fig. 7.

Type locality: South Africa.

**Material.**—WAM.262-70, series of 6 specimens, largest male of cl:16.5, cb:19.0, Loc: Flying Fish Cove, Christmas Island, Coll: Mr. Powell, 23.6.1961, Det: *proporciana*; NMS.1965.10.10.3 male, Loc: Cocos Keeling, Coll: Gibson Hill, 1941, Det: Tweedie, 1950, p. 108; NMS.1965.10.10.2, male of cl:10, cb:11.40, Loc: Christmas Island, Indian Ocean, Coll: Gibson Hill, 1940, Det: Tweedie, 1947, p. 281; NMS. 1965.10.10.1, Loc: Christmas Island, Coll: Ward, 1934, Paratype specimen of *K. proporciana* Ward, 1934, Balss (1938, p. 28) corrected as *rugulosa*.

**Remarks.**—The two chelipeds differ slightly; one has its palm a little longer and higher with rugae of the outer surface more marked than the other. The male pleopod is like that illustrated by Barnard (1950) and has a distally broadened apex with a subdistal bunch of long setae; it also has some heavy short pre-apical spines which are not indicated on Barnard's figure. Laurie (1906), examining the type of *porcellana*, stated it to be identical with *rugulosa* as suggested by Dana (1852). Ward (1934) separated *proporciana* from *rugulosa* and considers *porcellana* as a distinct species. The syntype of *proporciana* deposited in the National Museum of Singapore does not present any discrepancy in regard to the present series and confirms the views of Balss on the identity of the two forms. However, the comparison of the Type specimen of *rugulosa* or a topotype from South Africa or material from Japan and Hawaii with the types of the species of *proporciana* and *porcellana* (the two in the British Museum) could suggest that more than one species should be recognised.



Figure 1.—Male pleopods 1 and 2 of *K. rugulosa*, WAM 262-70 of cl:16.0, cb:16.5.

The recorded size of specimens are by De Man (1887) 17.5x20.75; Sakai (1939) a male of 17x20; Barnard (1950) one male of 13x15 and one female of 11x12; Ward (1934) three specimens of 8.5, 10, 12 as carapace width. The species is recorded from South Africa (Krauss, Stebbing, Barnard), Philippines (White), Hawaii (Dana, Rathbun, Edmondson), Mergui Archipelago (De Man), Minikoi, Laccadives (Borradaile), Gilbert Islands, Ellice Islands, Samoa Islands, Marshall Islands (Balss), Christmas Islands in Indian Ocean (Ward), Tweedie, Cocos Keeling Islands (Tweedie), Timor (Buitendijk), Japan, Formosa (Urita, Sakai).

***Kraussia quadriceps* Yokoya 1936**

(Figs. 3, 4, 23B)

*Kraussia quadriceps*, Yokoya, 1936, p. 143, fig. 9.—Sakai, 1939, p. 431.

Type locality: Japan.

**Material.**—WAM.266-70, male of cl:17, cb:19, Loc: North Steamboat Island, Dampier Archipelago, N.W.A., 14 faths Hon. drge, Coll: Royce on "Davena", Date coll: 27.5.1966; WAM.273-70, male of cl:10, cb:11.5, Loc: 20 miles N. of Delambre Is., Dampier Arch., N.W.A., Source: B. R. Wilson on "Davena", Date coll: 7/6/1960; NMS. 1970.1.3.1., female with cl:12.00, cb:13.00, carapace with only one cheliped and no other

pereopod, Loc: Colombo, Ceylon, R. Serene coll. 1966.

**Observations.**—The present specimens have: (1) the front salient with four lobes anteriorly rounded (the left is damaged on the illustrated specimen and deeply separated).—2) the two chelipeds similarly shaped, with the palm and fingers elongate and smooth, but slightly unequal; one cheliped is a little longer than the other with palm less high; the cutting edge of the fixed finger of shorter cheliped has an elongate subdistal tooth, which is very feeble on the other cheliped. Also, the cutting edge of dactylus of the shorter cheliped has a proximal low tooth which does not exist on the other cheliped.—3) a notch marking the posterior limit of the anterior third of lateral border and with a distinct tooth behind; a second notch situated more posteriorly is well marked.—4) the dactyli of pereopods 2-5 sickle shaped and elongate with concave anterior border.

Their identity with *quadriceps* appears valid. The low elongate tooth of the cutting edge of the fixed finger is not indicated on the description of Yokoya (1936), who only mentions: "thumb of chela normally well developed." The male pleopod 1 has its apex bent nearly at right angle to form a transverse beak and presents on one side a large bunch of very long setae. Examination of the type specimen for these

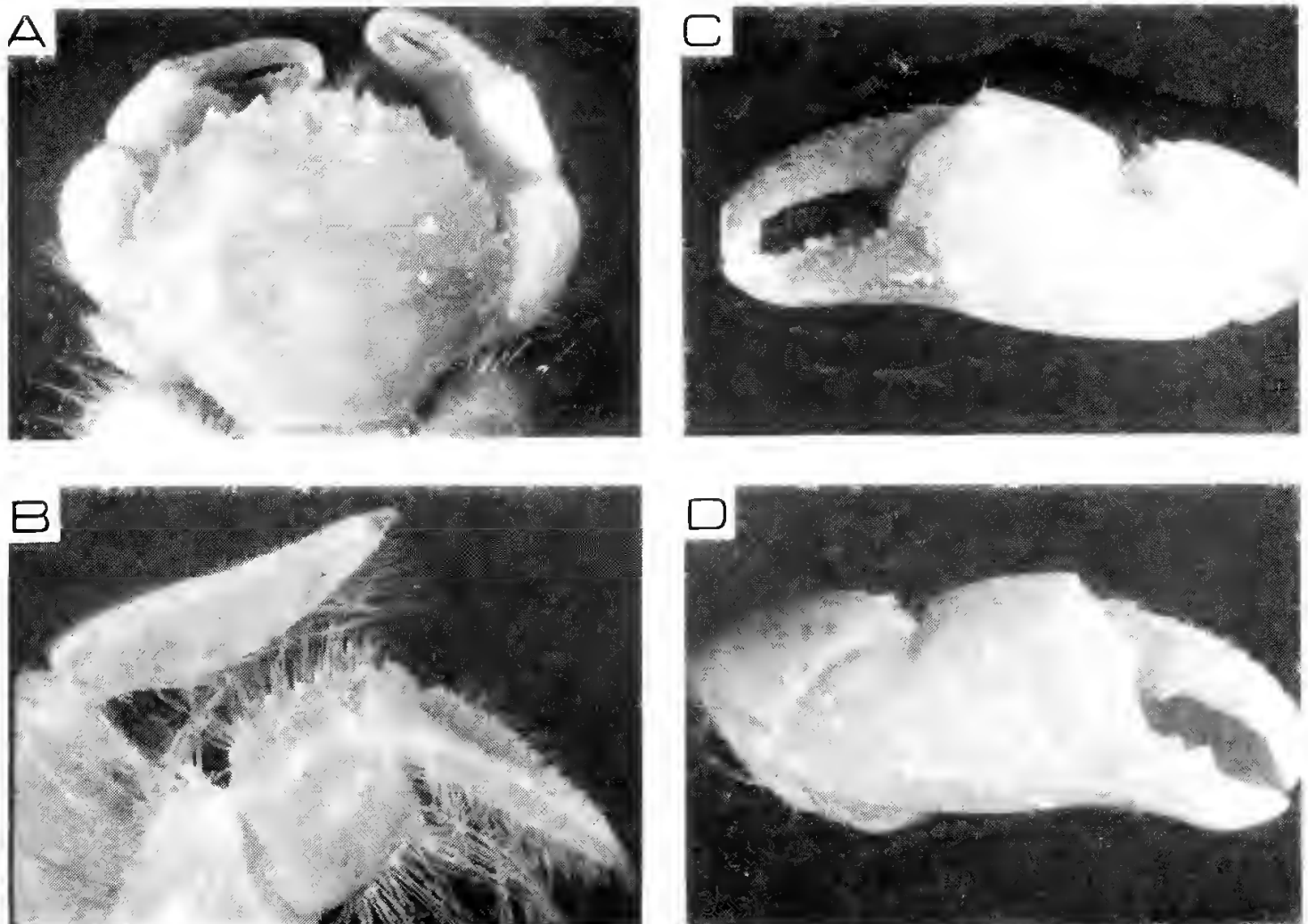


Figure 2.—*Kraussia rugulosa*, WAM 232-70, male of cl:16.5, cb:19.0. A, entire animal.—B, pereopods 4, 5 (ventral view).—C, right cheliped.—D, left cheliped.

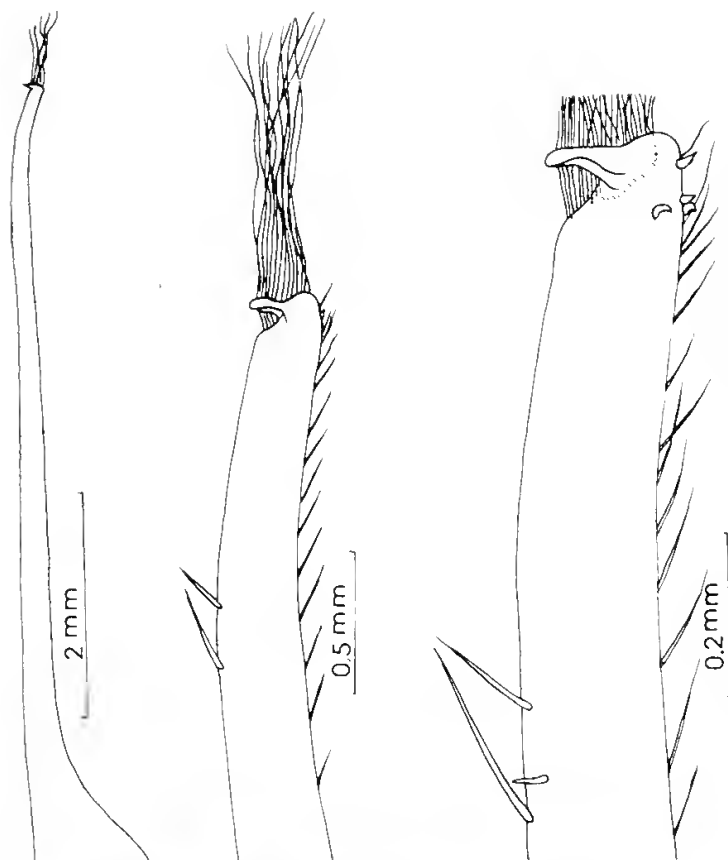


Figure 3.—Male pleopod 1 of *K. quadriceps*, WAM 266-70 of cl:15.3, cb:16.6.

characters of the male pleopod 1 and for the fixed finger would confirm or modify the present identification.

On the largest specimen the dactyli of the pereopod 5 are missing on the two sides. Those of the smaller specimens (273) are illustrated as indicated on the text of the plate. The fronto-orbital breadth of *quadriceps* is comparatively narrower than any other species of *Kraussia* and is clearly less than half of the largest breadth of the carapace. In all other species it is a little more than half. *K. quadriceps* was previously known by the single type specimen, a male of cl:10.7, cb:11.3, from Japan.

***Kraussia wilsoni* nov. sp.**

(Figs. 5, 6, 23C)

Type specimen: Western Australian Museum, Perth.

Type locality: off Siasi Island, Sulu Archipelago.

*Type material*.—Holotype, WAM.278-70, male of cl:11, cb:12; Paratype, WAM.143-71, female of cl:9, cb:10.5, Loc: North of Siasi Is., Sulu Arch., 20-22 faths., sponges, coral and sand, Coll: B. R. Wilson on "Pele", 17/2/1964; WAM.38-71, one female of cl:8, cb:9, Loc:  $\frac{1}{2}$  mile from Don Can Is., Laparan Group, Sulu Arch., 30 faths., sand and lithothamnion, Coll: B. R. Wilson on "Pele", 21/2/1964.

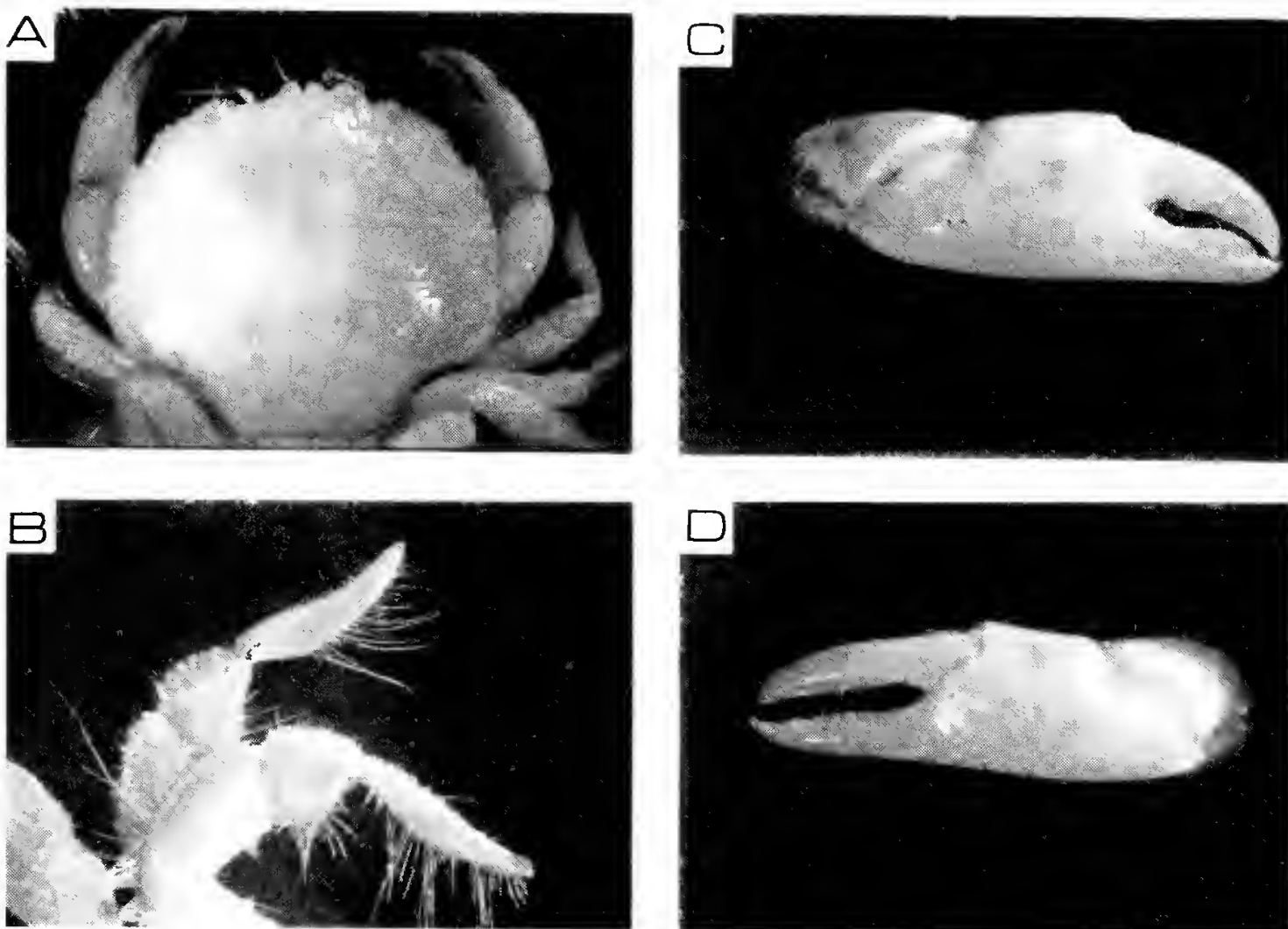


Figure 4.—*Kraussia quadriceps*, WAM 266-70, male of cl:17.0, cb:19.0 A, dorsal view.—B, pereopods 4, 5 (of WAM 273).—C, right cheliped.—D, left cheliped.

**Diagnosis.**—Carapace nearly smooth, punctuate with some granules on the area close to frontal and antero-lateral margins. Frontal margin consists of four round lobes, only a little salient beyond the inner supra orbital angle which is blunt, like the extraorbital angle. Antero-lateral margin of carapace with a feeble notch. Both chelipeds smooth with same length but one with palm higher and finger a little shorter than on the other. Both fingers relatively strong, normally developed, longitudinally carinate, their length clearly less (0.65 on major cheliped, 0.78 on minor cheliped) than height of palm; cutting edge of fixed finger of major cheliped with a low elongate subdistal tooth; cutting edge of dactylus with a proximal large low tooth. No clear tooth on cutting edge of fingers of minor cheliped. On both chelipeds brown colour of fixed finger extends a little on palm. Anterior border of the pereopods 2-5 nearly straight with a longitudinal row of small granules. Granules a little acute and extend nearly all along on pereopod 2; feeble on pereopod 5 and limited to the proximal part on pereopods 3 and 4. Male pleopod devoid of any bunch of setae, with truncate apex, ornamented with subdistal acute spinules, larger and more numerous on outer side.



Figure 5.—Male pleopod 1 of *K. wilsoni*, WAM 278-70 of cl:10.0. cb:10.8

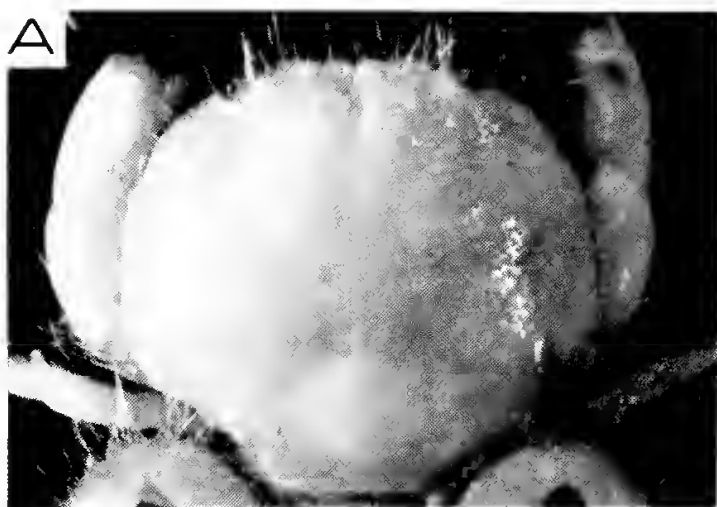


Figure 6.—*Kraussia wilsoni*, WAM 278-70, male of cl:11.0, cb:12.0. A, dorsal view.—B, pereopods 2, 3.—C, major cheliped.—D, minor cheliped.



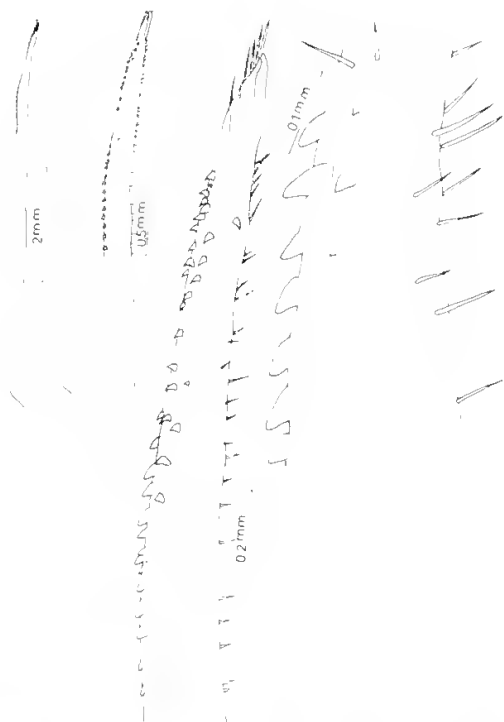


Figure 7.—Male pleopod 1 of *K. pelsartensis*, WAM 265-70 of cl:13.3, cb: 15.6.

**Observations.**—The paratype (smaller female) has the pre-distal tooth developed on the cutting edge of the fixed finger of the two chelipeds. Such a difference could be related to the different size as well as to the sex of the specimen. On the small female (WAM38-71) the discrepancies in regard to the holotype is more accentuated; the difference between the major and the minor chelipeds is stronger, the major having comparatively a palm higher and the fingers shorter; the tooth on the cutting edge of the fixed finger is particularly large. The minor cheliped is more elongate, with dactylus more deeply carinate and granular on superior border. The extension of the brown colour of the fixed finger on the palm is already marked.

By the shape of its carapace and chelipeds, *wilsoni* is closer to *quadriceps* than to any other species, but it clearly differs by several characters of the front, the chelipeds, the dactyli of the pereopods 2-5 and the male pleopod 1. The fronto-orbital breadth is clearly more than half the largest breadth of the carapace, instead of being clearly less on *quadriceps*.

The species is dedicated to Dr. B. R. Wilson from the Western Australian Museum, who collected the Type material, as well as an important part of the other material used for the present paper.

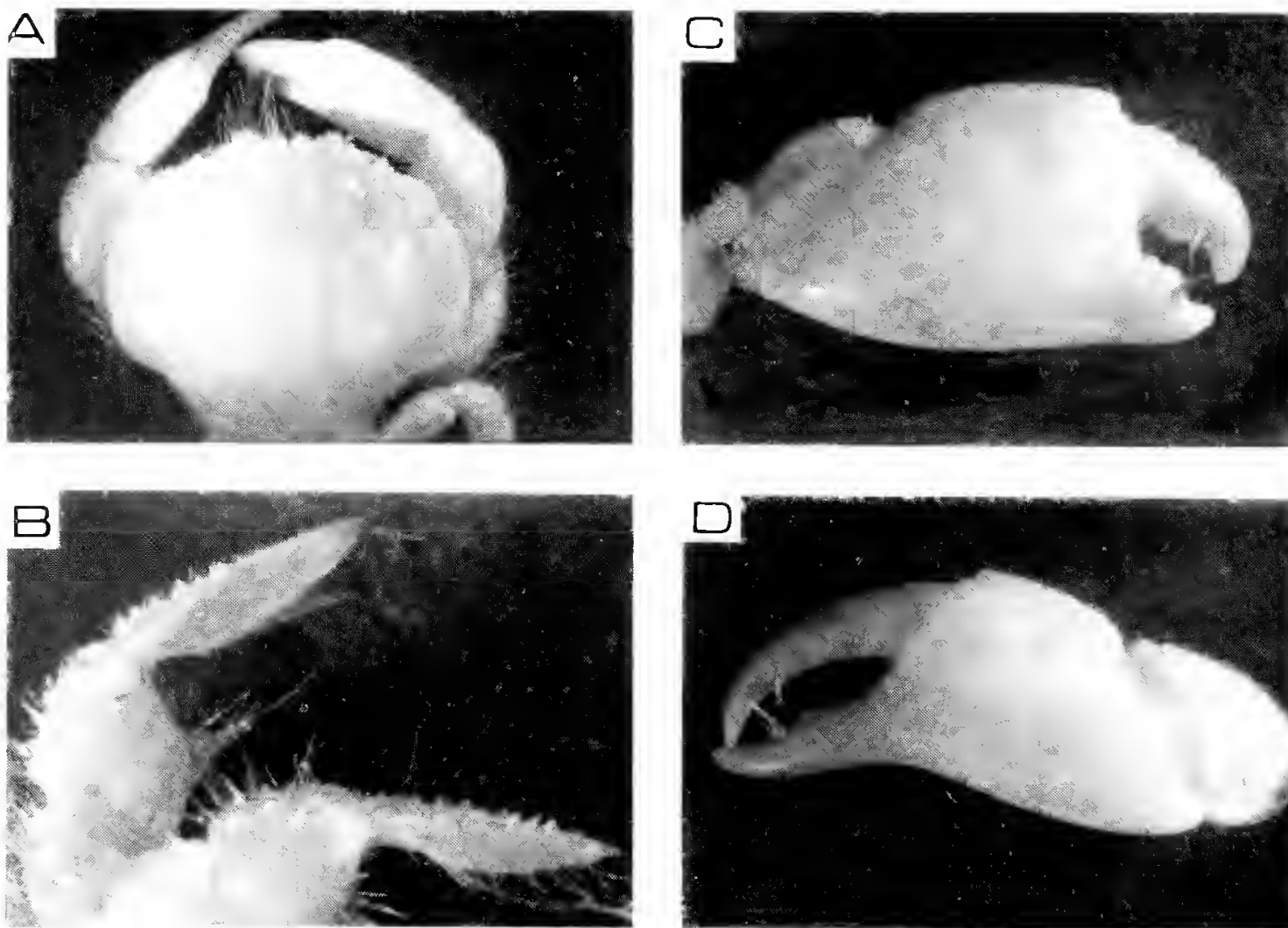


Figure 8.—*Kraussia pelsartensis*, WAM 265-70, male of cl:14.6, cb:18.0. A, dorsal view.—B, pereopods 4, 5 (of WAM 270).—C, major cheliped.—D, minor cheliped.



***Kraussia pelsartensis* nov. sp.**

(Figs. 7, 8, 23D)

Type specimen: Western Australian Museum, Perth.

Type locality: off Hummock Island, Pelsart group, Abrolhos.

**Material.**—Holotype, WAM.265-70, male of cl:14.6, cb:18, lacking pereopods 2-5 on left side, and pereopod 4 on right side. Loc: 3 miles, west Hummock Island, Pelsart Group, Abrolhos, 20 faths., Source: R. W. George on "Davena", 2.6.1960; Paratypes, WAM.268-70, 2 males, one of cl:14.5, cb:18, another of cl:12, cb:14.5, Loc: Cape Vlaming, Rottnest Island, Source: B. R. Wilson, Date coll: 1/3/1962; WAM.270-70, male of cl:13, cb:16, Loc: S.W. of Point Cloates, 113° 39' 30"E, 22° 43' 30"S. Source: Ningaloo Exp'd., 7/9/1968; WAM. 274-70, 2 males, the largest of cl:19.5, cb:11, Loc: N.W. Rat Island, Abrolhos Group, Honolulu Dredge, 25 faths., coralline bank, Source: R. W. George on "Davena", Date coll: 12/5/1960.

**Diagnosis.**—Holotype. Carapace nearly smooth with some small flattened granules on the area close to the front and lateral border. Front quadrilobate with a deep open medium incision, little salient beyond the orbits. Inner supra orbital angle (preorbital spine) marked and

well separated from the front by the antennal sulcus but not acute. A small concavity is present behind extraorbital angle on antero-lateral margin of carapace, followed posteriorly by a convexity and a notch. Both chelipeds smooth, differently shaped but with palm of same length. Major cheliped with a swollen palm, as high as half its total length; both fingers short;



Figure 9.—Male pleopod of *K. roycei*. WAM 269-70 of cl:13.2, cb:14.

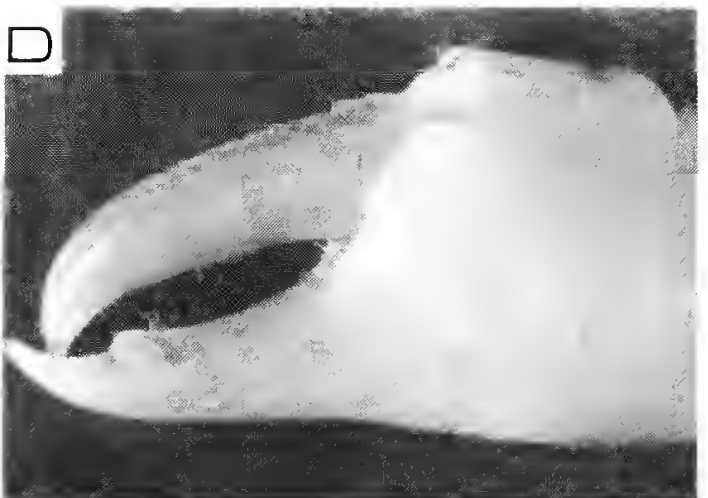
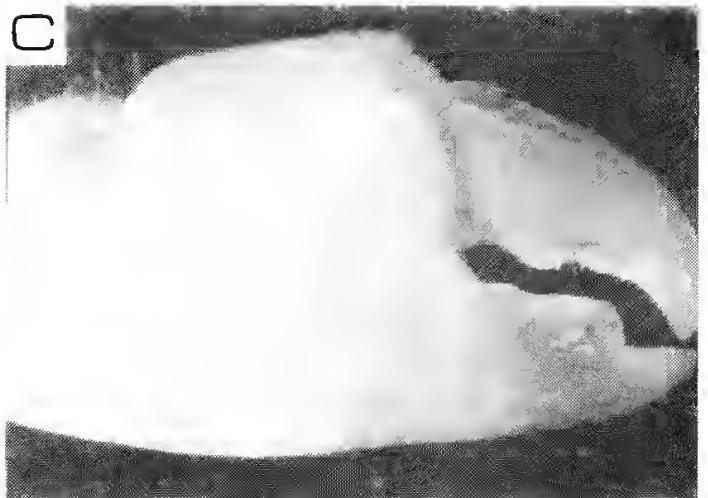
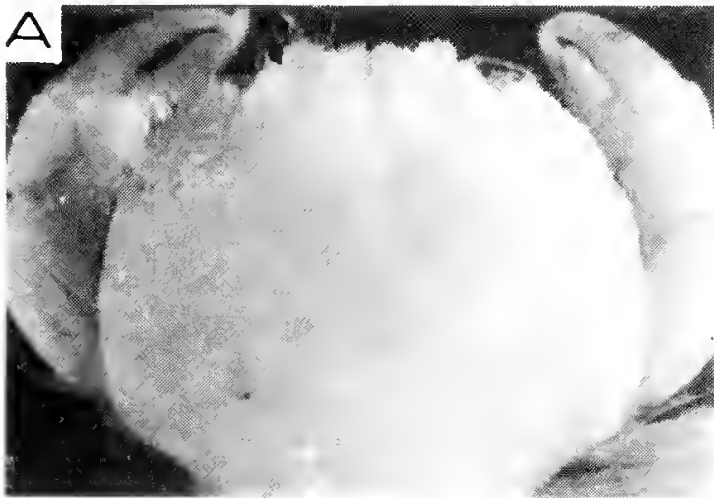


Figure 10.—*Kraussia roycei*, WAM 269-70, male of cl:13.2 cb:14. A, dorsal view.—B, pereopods 4, 5.—C, major cheliped.—D, minor cheliped.

fixed finger a little longer than one-third of height of palm. Dactylus with some granules on the proximal third of its superior border and one large rounded tooth on its cutting edge; fixed finger with two molariform teeth on its cutting edge, proximal tooth much smaller. Minor cheliped with palm somewhat elongate, clearly less high than half its length; both fingers, elongate, somewhat slim, tapering distally with tips crossing and a gap between them. Fixed finger nearly as long as height of palm; dactylus much longer; fixed finger bent downward, a concavity marking lower border of palm. Dactyli of pereopods 2-5 have anterior border nearly straight (feebly sinuous), posterior borders convex; all anterior border of pereopods 2 and 5 denticulate; only its proximal half denticulate on pereopod 3. Denticles stronger on pereopod 5; pereopods 4 missing on both sides of holotype. On paratype (WAM.270-70) anterior border of dactyli of pereopod 4 like on pereopod 3 of holotype but with denticle extending a little over its proximal half. Male pleopod with apex straight and ornamented on outer side by a subdistal row of 10 large but relatively short acicular setae; outer side of stem with a series of strong short spines on distal fifth part of its length, inner side only ornamented by some fine accicular spinules.

**Observations.**—On the largest male of the paratypes (WAM. 268-70), the two chelipeds are nearly similar with one another as size and shape; the two chelipeds have the palm and fingers elongate and are nearly like the minor cheliped of the holotype. The other paratype has only one cheliped which is like the minor cheliped of the holotype.

A somewhat smaller specimen (WAM.274-70) has the fingers of the major cheliped comparatively less shortened than on the holotype. The other specimen (WAM.274-70) is much smaller (probably juvenile) and has the two chelipeds clearly unequal and dissimilar, but the palm of the major cheliped is less swollen, the fingers are a little longer than in the holotype; the palm and fingers of the minor cheliped are a little shorter than in the holotype. The concavity behind the extraorbital angle is well marked. The dactyli of the pereopods 2-5 are identical with those of the paratype.

The conditions of the chelipeds of the largest paratype could mislead in the use of my key for its identification as *pelsartensis*. However, the species is well characterized by: (1) its broad carapace.—(2) the shape of the chelipeds.—(3) the small concavity behind the extraorbital border.—(4) the dactyli of the pereopods 2-5 with acute granules on anterior border more developed on the pereopods 2 and 5.—(5) the male pleopod. The name of the species refers to the Pelsart Group of the Abrolhos Islands, where the type material was collected.

***Kraussia roycei* nov. sp.**

(Figs. 9, 10, 23E)

Type specimen: Western Australian Museum.

Type locality: Dampier Archipelago, Australia.

**Material.**—Holotype, WAM.269-70, male of cl:13.2, cb:14, Loc: Flying from Passage,

Dampier Arch., Source: R.D. Royce on "Davena", Date coll: 30/5/1960.

**Diagnosis.**—Carapace with finely granular ripples all over. Front quadrilobate salient beyond the orbits and with nearly closed median incision. Inner supra orbital angle (pre-orbital spine) marked and antennal sulcus deep. Sinus on outer part of upper orbital border strongly marked and continued on carapace by a clear groove. Antero-lateral margin of carapace with only a feeble notch. Both chelipeds smooth with a palm of same height and same length but differently shaped; major cheliped with upper border of palm longer and two fingers shorter than on minor cheliped. Two fingers a little shorter than height of palm on major cheliped, much longer than height of palm on minor cheliped. Cutting edge of fixed finger of major cheliped with two low molariform teeth, the proximal feeble; that of minor cheliped with a strong subdistal tooth. Dactyli of pereopods 3,4,5 with anterior border slightly concave without denticle; that of pereopod 2 more straight with 2-3 small denticles on proximal half. Male pleopod with apex like a short beak bent at 45°, a subdistal bunch of long setae on ventral side, a pre-apical series of acute short thick spines on dorsal side and some similar spines at some distance on outer side of the stem.

**Observations.**—The species is close to *pelsartensis* and on first examination was considered only as a variety. The discrepancies of the male pleopod in particular supported the view of separate species. The holotype of *roycei* was compared with all the available material of *pelsartensis*, but particularly with the male of 13x16 (WAM.270-70) which has a carapace length nearly equal to that of *roycei*.

*K. roycei* differs from *pelsartensis* by the following characters: (1) The breadth of the carapace is 1.07 times its length, instead of being 1.22; the fronto orbital breadth is 1.86 instead of being 2.06 in *pelsartensis*.—(2) the front is comparatively more salient beyond the inner supra-orbital angle; the sinus of the upper orbital border more marked; the postfrontal region is more densely covered with long hairs than on *pelsartensis*, in which the hairs are limited around the frontal margin.—(3) There is no trace of the feeble but always clear concavity which marks the antero-lateral border of the carapace immediately behind the extraorbital border on *pelsartensis*.—(4) The carapace is more granular, the granules being arranged in fine transverse ripples.—(5) The merus of the cheliped does not have on the distal margin of the upper border, the distal spinule which exists on *pelsartensis*. The major cheliped differs less from the minor cheliped than on *pelsartensis*. The fingers of the major cheliped are longer and those of the minor shorter than on *pelsartensis*.—(6) The dactyli of pereopods 3-5 have the anterior border slightly concave without denticles instead of nearly straight with denticles on *pelsartensis*.—(7) the male pleopod with the apex like a short beak bent at 45° instead of straight on *pelsartensis*.

To support the discrepancy of the breadth of the carapace, the measurements of the specimens of *pelsartensis* (indicated by their regis-

tered number) in regard to those of *roycei* are given in the table below:

The species is dedicated to its collector, Mr. R. D. Royce.

**Kraussia nitida Stimpson 1858**

*Kraussia nitida*, Stimpson, 1858, p. 40.—1907, p. 87, pl. 10 fig. 4.—Miers, 1884, p. 235.—Henderson, 1893, p. 379, pl. 37, fig. 9.—Alcock, 1899, p. 98.—Calman, 1900, p. 24.—Rathbun, 1902, p. 132, fig. 13—1910, p. 366.—1911, p. 211.—Laurie, 1906, p. 421.—Balss, 1922, p. 98.—1935, p. 131—1938, p. 271, fig. 11, 12.—Urita, 1926, p. 11.—Sakai, 1934, p. 305.—1935, p. 133, pl. 41, fig. 2.—1939, p. 430, pl. 52, fig. 2, text-fig. 20.—1965, p. 107, pl. 49, fig. 2.

*Kraussia integra*, Borradaile, 1902, p. 270 not *integra* De Haan fide Rathbun 1902.

?*Kraussia hendersoni* (under *nitida* pars), Rathbun, 1902, p. 132.

?*Kraussia hendersoni*, Rathbun, 1906, p. 875, pl. 14, fig. 2.—Balss, 1922, p. 98.—Montgomery, 1931, p. 433.

Type locality: Kagosima, Japan.

**Preliminary remarks.**—The descriptions and illustrations of *nitida* in the literature are ambiguous. In the absence of the type specimen which is lost like the main part of Stimpson's material, no better reference exists. The selection of a topotype specimen from Kagosima (or at least Japan), its designation as neotype and a redescription of the species seems to be necessary. Sakai (1934) records one made from Kagosima. Provisionally the descriptions and illustrations of *nitida* by Stimpson (1858, 1910) and Sakai (1939, 1965) for Japanese specimens must be considered as the most accurate. By their shorter and thicker chelipeds, the specimens from the Maldives illustrated by Rathbun (1902) and from Australia illustrated by Balss (1938) seem to belong to a different species. The specimen of Sakai is a little larger (9x9.5) than that of Rathbun (7.7x8.4) and a little smaller than that of Balss (10.5x13).

A specimen from the Irian Gulf is identified with reserve (*nitida* Stimpson?) by Stephensen (1945) and as such the illustration of its male pleopod cannot be used as reference for *nitida*. Only a re-examination of the type specimen of *hendersoni* (in the USNM) will allow one to confirm or deny the validity of the species contested by Balss (1935) but not by Sakai (1965).

The species *nitida* s.l., as it is understood by Balss (1938) for example, seems to correspond to a composite taxon including two or three different species, and it must be considered that no accurate definition of *nitida* exists.

***Kraussia ?nitida* Stimpson 1858**

(Fig. 11)

**Material.**—WAM.260-70, one female of cl:7, cb:7.5, Loc: West Approaches to Mermaid Str., Dampier Archipelago, W.A. Coll: R. D. Royce on

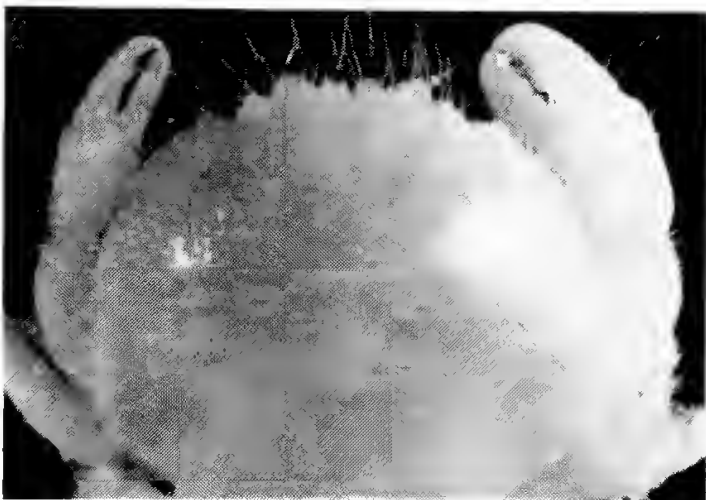


Figure 11.—*Kraussia nitida?* WAM 261-70, female of cl:7, cb:7.5.

"Davena", 27.4.1960, Det: M. E. Clarke as *nitida*; WAM. 261-70, female of cl:12.2, cb:13, Loc: off Cape Cleveland Qsld., dredged 16 faths., Coll: W. Goode on "Dorothea", 24.11.1962, Det: M. E. Clarke as *K. nitida*.

**Observations.**—The two specimens have the lobes of the frontal border rounded. The chelipeds of the largest specimen (WAM 261-70) perfectly agree with the figures of *nitida* by Balss (1938) which illustrates a female of the same size. Even the fixed finger of the major cheliped has the two teeth on the cutting edge as illustrated by Balss (1938) the distal being comparatively much larger. On the minor cheliped, the fingers are a little larger and an elongate subdistal tooth is well developed on the cutting edge of the fixed finger. A re-examination of Balss's material or other new material from Australia and its comparison with Japanese material could demonstrate that these specimens belong to a species distinct from *nitida*. The specimens, being females, cannot provide information on the pleopod, and the use of the present material as type for a new species will be unwise. On the smaller specimen the palm and fingers, mainly of the minor cheliped, are much more elongate. Such material emphasizes the uncertain situation of *nitida* as understood by Balss (1938).

***Kraussia aff. nitida***

(Figs. 12, 13, 23F)

*Kraussia (nitida* Stimpson?), Stephensen, 1945, p. 138, fig. 33.

**Material.**—NMS.1965.10.10.6, male of cl:10.5, cb:12, Loc: Pulau Paway, off Singapore. Coll: Tweedie 1934, Det: as *nitida* by Balss 1938, (handwritten label), not recorded in literature.

	(265)	(268A)	(268B)	(270)	(274)	<i>roycei</i>
carapace length	14.6	14.5	12	13	9	13.2
carapace breadth	18	17.8	14.5	16	11	14
ratio cb : cl	1.23	1.22	1.20	1.22	1.22	1.07

**Diagnosis.**—Frontal border feebly quadrilobate, median incision shallow, rounded lateral lobes little prominent and separated by a feeble concavity. Inner supra orbital angle little prominent and antennal sulcus shallow.

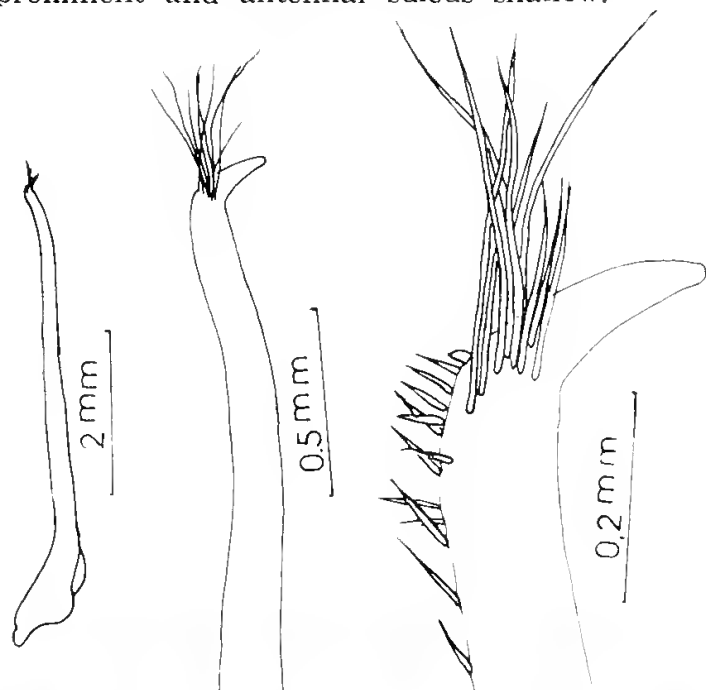


Figure 12.—Male pleopod 1 of *K. aff. nitida*, NMS. 1965.10.10.6 of cl:9.8, cb:10.8.

Two chelipeds with palm of same length; major cheliped with palm higher, upper border of palm longer and two fingers shorter than on minor cheliped. Fixed finger of major cheliped clearly shorter than half height of palm, of minor cheliped clearly longer than half height of palm. Outer surface of palm ornamented with a distal vertical row of large granules, and some other smaller granules distributed on distal half. Both chelipeds with superior border of dactyli canaliculated and granular on proximal half. Dactyli of pereopods 2-4 sickle-shaped and relatively elongate. Male pleopod 1 with apex bent nearly at right angle and a subdistal bunch of long setae; inner side of pre-apical region ornamented with a row of 13-14 acicular spines.

**Observations.**—The frontal margin with round lobes differs strongly from that of *nitida* illustrated by Sakai (1939) for a specimen of nearly the same size, as well as from the illustrations of any other authors. The chelipeds are nearly similar to those illustrated by Balss (1938, fig. 11, 12); the palm of the major cheliped is higher on Balss's figure than on the present specimen. On the figure of Balss (1938, fig. 11) the height of the palm is 0.62 its total length (fixed finger included) and 2.7 the length of the

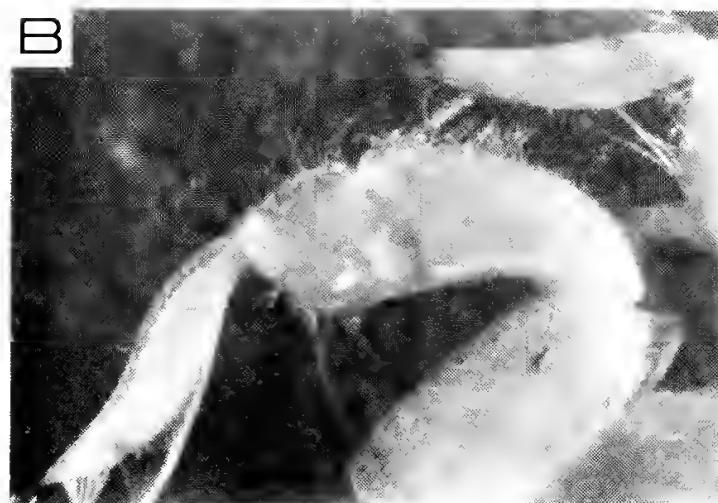
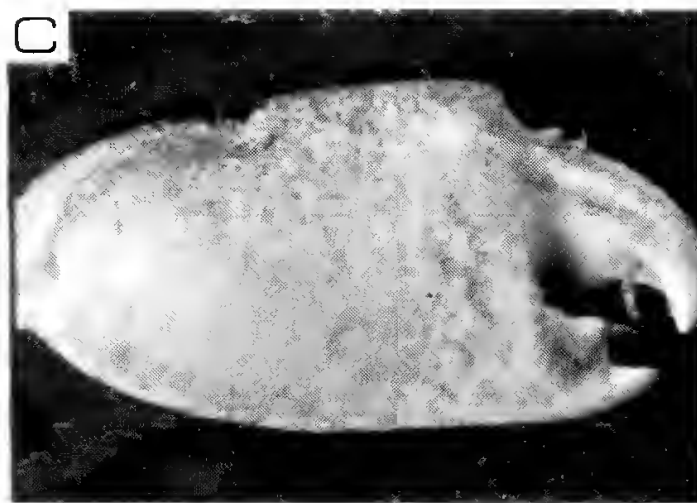
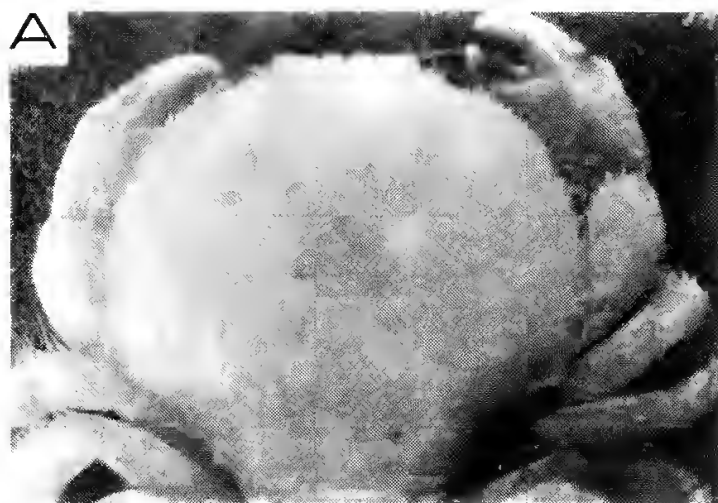


Figure 13.—*Kraussia aff. nitida*, NMS.1965.10.10.6, male of cl:9.8, cb:10.8. A, dorsal view.—B, pereopods 4, 5.—C, major cheliped.—D, minor cheliped



fixed finger; on the present specimen it is respectively 0.56 and 2.5. The specimen of Balss (1938) was a female from Shark Bay, probably of breadth of carapace 14 supposing that he had illustrated his larger specimen; Balss records for 3 females from Shark Bay carapace breadths of 14, 11, 13.

Stephensen (1945) mentions that his specimen has the hands more slender than on the figures of Balss (1938) and also that "the fixed finger in right chela has but one tooth (besides the apical tooth) and the movable fingers of the hands are on the convex side smooth, not denticulate." The present specimen seems to agree with the first two characters given by Stephensen, but it has the dactyli clearly denticulate. The male pleopod of the present specimen is identical with that illustrated by Stephensen (1945, fig. 33) and suggests that the two specimens belong to the same species. The material of Balss (1938) or a part of it could also belong to the present form, of which the identity with *nitida* Stimpson has still to be demonstrated.

***Kraussia marquesa* nov. sp.**

(Figs. 14, 15, 23G and H)

Type specimen: Western Australian Museum.

Type locality: Anaa Atoll, Marquesas Island.

**Material.**—Holotype (WAM.264-70), male of cl.12.7 x cb:14; pereopods 2-5 left side missing, pereopod 2 right side separated but present, Loc: Anaa Atoll, Sta An IV + V, depth 30-60 feet, Coll: Marquesas Exped. 1967, Date: 29.10.1967; ? NMS.1969.11.20.5, male of cl:15.33, cb:18.66, Loc: Puerto Galera, Mindoro, Philippines, Coll: Univ. Philippines. One cheliped missing, only two ambulatory legs present. Dry specimen now re-generated and maintained in alcohol.

**Diagnosis.**—(Holotype). Carapace strongly granular all over; the margin of carapace with strong and acute granules. Front quadrilobate, salient beyond orbit and with an open deep median incision. Antennal notch well marked; no trace of sinus on upper orbital border. Lateral margin of carapace with feeble but clearly indicated lateral notch. Two chelipeds similar with high palm and short fingers. Fixed finger of right cheliped approximately one-third of height of palm, of the left cheliped one-fourth of the height of palm. Outer surface of the palm strongly granular with black pigment of fixed finger extending on palm.

Dactyli of pereopods 2 and 5 with strong acute granules on anterior border; one row of granules on that of pereopod 2 and two rows on that of pereopod 5; the dactyli of pereopods 3 and 4 sickle-shaped, and without granules on anterior border. Male pleopod 1 with apex nearly straight (a little bent) with a few subdistal long acicular setae and some strong short pre-apical spines.

**Observations.**—By its chelipeds with very high palm and short fingers, *marquesa* differs from *nitida* as illustrated by Stimpson (1907) and

Sakai (1939, 1965) as well as from *nitida* illustrated by Balss (1938). The two chelipeds with high palm and short fingers, the black pigment of the fixed finger extended on the palm as well as the strong granulation of the carapace of *marquesa* are characters close to those of *integra* and *bongensis* as described and illustrated in the present paper. *K. marquesa* differs from the two by the antennal sinus separating the front from the inner supra orbital angle, and the absence of sinus on the supra orbital border. That sinus is on those species always well marked and continued on the dorsal surface of the carapace by a longitudinal depression, distinctly indicated on the figure of Sakai (1939, 1965) and very clear on the specimens of the present collection.

The extension of the black pigment on the palm has, in my opinion, specific value as a character and must lead to a comparison of *marquesa* with *hendersoni*, a species separated from *nitida* by Rathbun (1902) mainly on the basis of the black pigment of the palm and the different shape of the front.

The specimen from Puerto Galera is identified with reserve as *marquesa*. It strongly differs from the holotype by its frontal border with median incision deeper and lateral lobes triangular and deeply excavated, inner supra-orbital

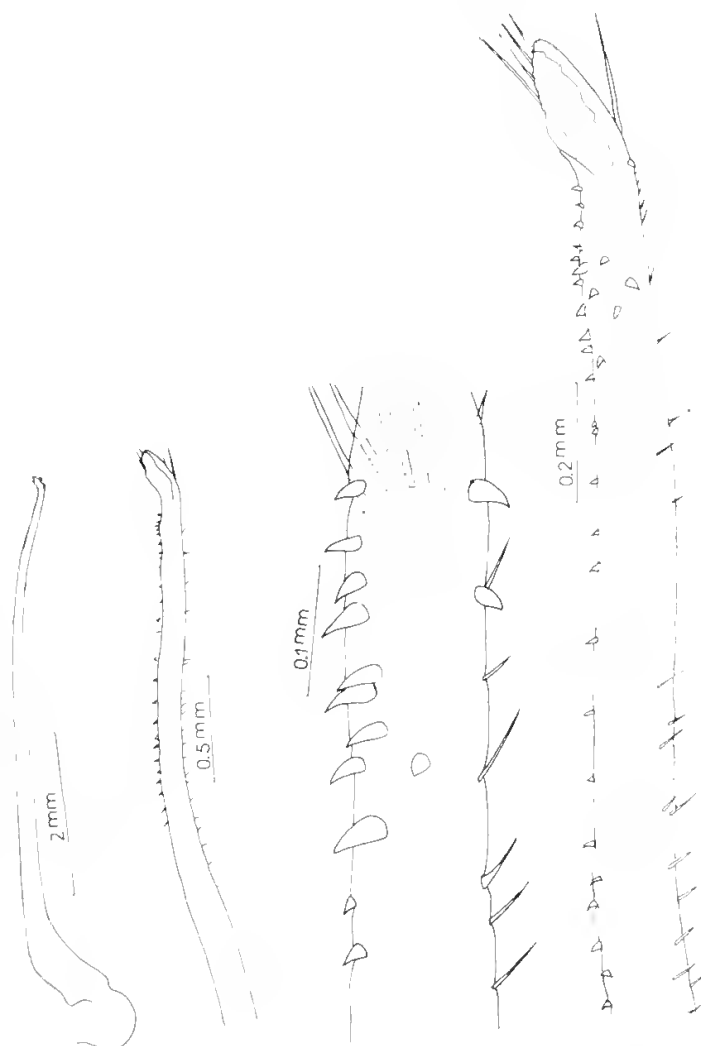


Figure 14.—Male pleopod 1 of *K. marquesa*, WAM 264-70 of cl:12.2, cb:14.

angle more acute, antennal notch deeper. (On the specimen the right inner supra-orbital lobe is broken). These characters agree with those described by Stimpson (1848, 1907), mentioned by Miers (1884), Henderson (1893), Alcock (1899), and illustrated by Henderson (1893, pl. 39, fig. 9), Stimpson (1907, pl. 10, fig. 4) and Sakai (1939, text-fig. 20, pl. 52, fig. 2 and 1965, pl. 49, fig. 2) for *nitida*.

Also its carapace is broader and front narrower than on the holotype. Measurements of the carapace of the holotype (1), the Puerto Galera's specimen (2) and the specimen identified *aff. nitida* (3) give the following ratios:

	(1)	(2)	(3)
carapace breadth/carapace length	1.14	1.19	1.10
frontal breadth/carapace length	0.40	0.38	0.40
frontal breadth/carapace breadth	0.35	0.32	0.37
fronto-orbital breadth/carapace breadth	0.55	0.53	0.55

The specimen of Puerto Galera has a carapace broader, and a front narrower, than the holotype of *marquesa* and the specimen of *aff. nitida*, which has the same frontal breadth as *marquesa* but a narrower carapace.

Rathbun (1902) indicates that on *nitida* "the fronto-orbital width is nearly two-thirds the full width of carapace" and on *hendersoni* "only half as great as that of carapace". By its narrower front as well as by the shape of its frontal margin the specimen of Puerto Galera is close to *hendersoni*. The chelipeds of *hendersoni* are slightly but clearly unequal on the photograph published by Rathbun (1906, pl. 14, fig. 2) and unfortunately the present specimen has only one cheliped. Besides, its male pleopod is so close to that of *marquesa* that at least provisionally it is considered as belonging to the same species. The name is a Spanish noble rank and recalls the area of the type material: Marquesas Island.

### *Kraussia integra* (De Haan 1835)

(Figs. 16, 17, 18, 23 I)

*Cancer (Xantho) integer*, De Haan, 1835, p. 66, pl. 13, fig. 6.

*Actumnus integra*, Richters, 1880, pl. 16, fig. 17, 18.

*Kraussia integra*, Rathbun, 1906, p. 875, pl. 14, fig. 3.—1911, p. 211.—Balss, 1922, p. 97 (no material).—1933, p. 29.—Gordon, 1931, p. 527 (in a list).—Sakai, 1934, p. 304, text-fig. 17a.—1936, p. 137, pl. 14, fig. 1, text-fig. 64.—1939, p. 429, pl. 52, fig. 1.—1965, p. 107, pl. 49, fig. 1.—Buitendijk, 1963, p. 233, fig. 1a.

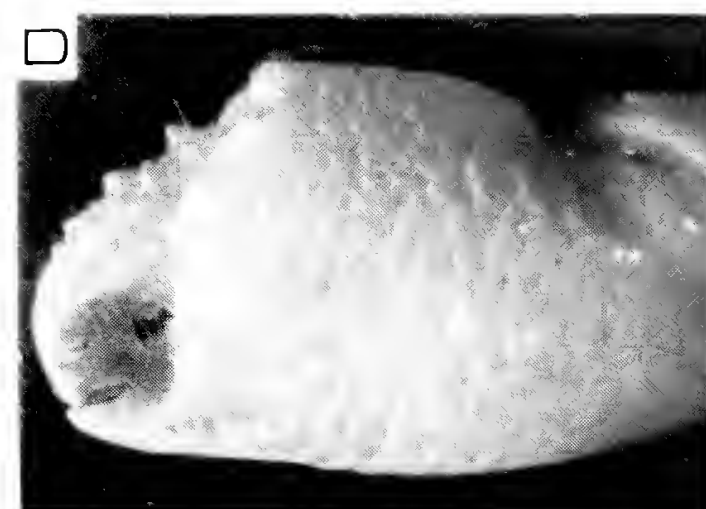
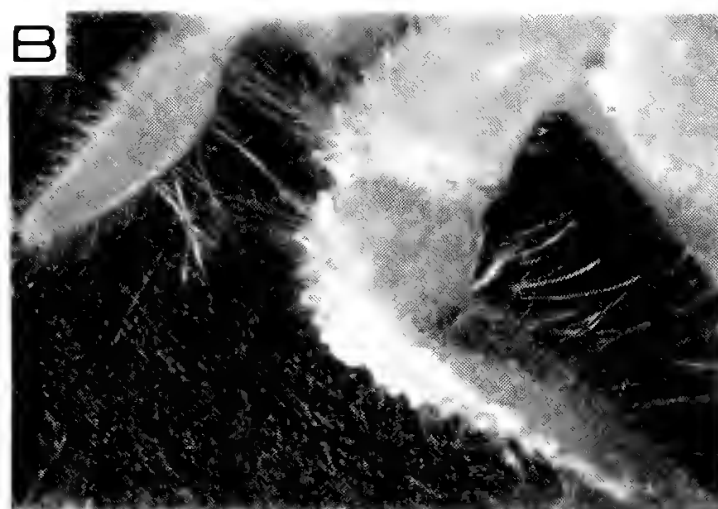
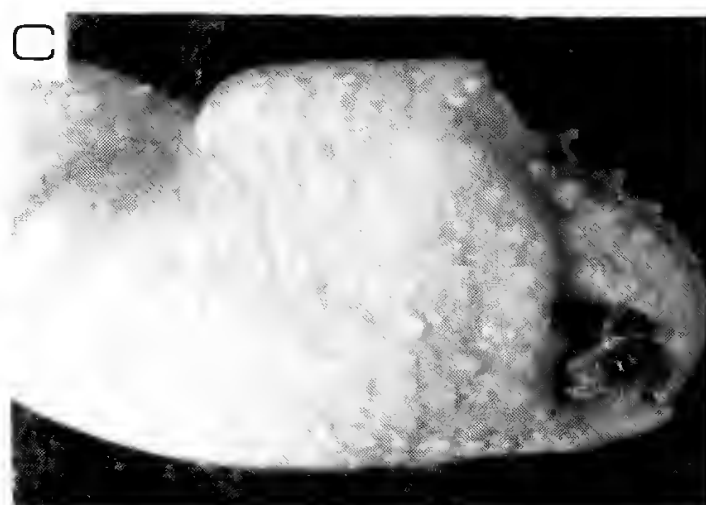
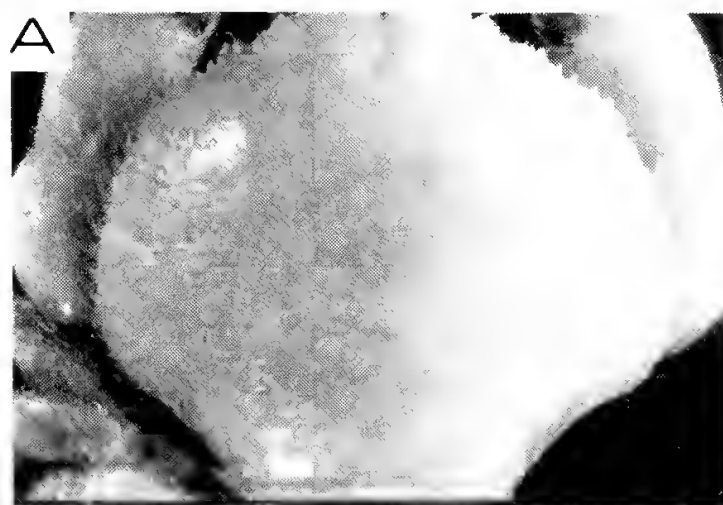


Figure 15.—*Kraussia marquesa*, WAM 264-70, male of cl:12.7, cb:14. A, dorsal view.—B, pereopods 4, 5.—C, right cheliped.—D, left cheliped.



Not *Kraussia integra*, Borradaile, 1902, p. 270  
*nitida* ãde Rathbun 1902.

Not *Kraussia integra*, Alcock, 1899, p. 97 — *rastripes*.

Not *Kraussia integra*, Tweedie, 1950, p. 108 = *ras-*  
*tripes*.

Type locality: Japan.

**Material.**—WAM.134-70, male of cl:15.33, cb:17.33, another much smaller specimen, Loc: 7 miles 260° from Zal Island Pearl Bank, Sulu Arch., Col: B. R. Wilson on Pele Exped. 21/2/1964, 10 fathoms, lithothamnion and sand; WAM.271-70, female of cl:12, cb:13, with only one cheliped. Loc: Stn. 2 E. of Cape Poivre, 20° 53'S, 115° 20'E. Date col: 24/8/1966, Hab: sand flats with rocks and sponges under stones, inter-tidal; WAM. 275-70, male of cl:10, cb:11 and one female of cl:13, cb:14, Loc: ½ mile S.W. of Don Can Is., Laparan Group, Sulu Arch., Source: B. R. Wilson on "Pele", Date coll: 21/2/1964, 30 faths., sand and lithothamnion; WAM. 276-70, damaged male of cl:9, cb:10.5. Loc: Sulu Archipelago, Source: B. R. Wilson on "Pele", Date coll. 2/3/1964; WAM. 277-70, male of cl:16, cb:19.5, Loc: 6-7 miles of Pearl Bank, Sulu Arch., 9-12 faths., coarse sand, Source: B. R. Wilson on "Pele", Date coll: 21/2/1964.

—Mariel King Memorial Expedition 1970: KR VI, north of Du Rowa Is., N. of Nuhu Rowa, Kai Islands, 5° 32'S, 132° 41'E; H3-10, 20 faths.,



Figure 13.—Male pleopod 1 of *K. integra* WAM 277-70 of cl:17, cb:19.5.

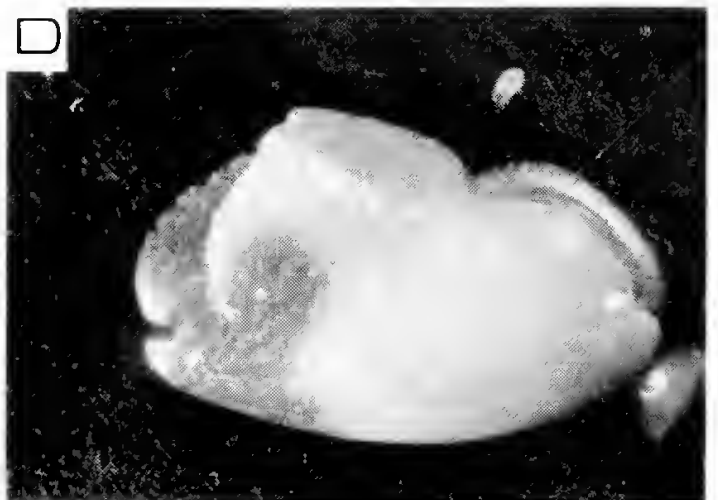
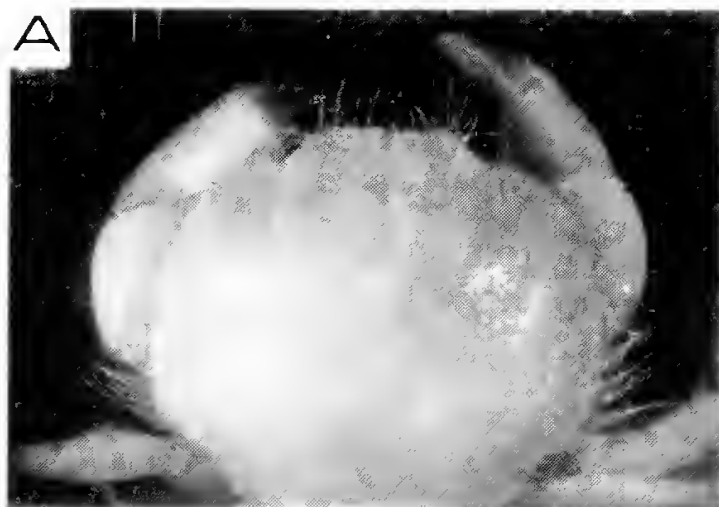


Figure 17.—*Kraussia integra*, WAM 277-70, male of cl:16, cb:19.5. A, dorsal view.—B, pereopods 4, 5.—C, right cheliped.—D, left cheliped.

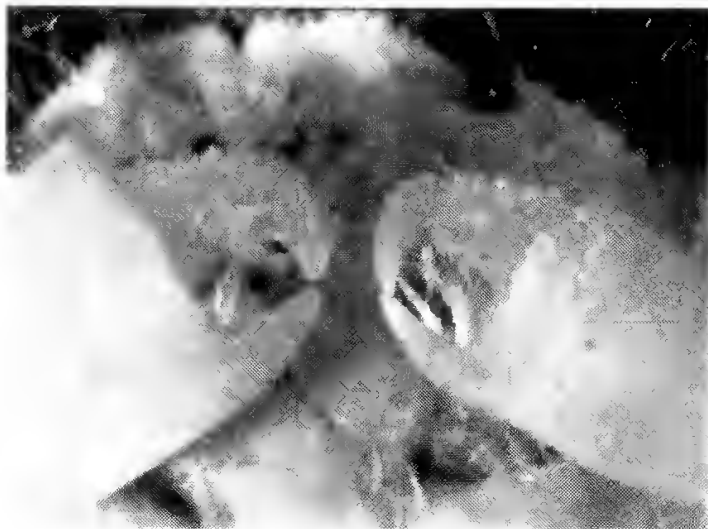


Figure 13.—*Kraussia integra*, KR VI/H3-10, male of cl:9, cb:10, cheliped of juvenile.

sand and rubble, Date coll: 10/6/1970; KN II, off Elat Bay, west coast Nuhu Tjut, Kai, 5° 40'S, 139° 59'E; H3-4, 27-35 fms., rubble, fan coral, some sand and green algae, Date coll: 13/6/1970; CP II, off Tg. Tutuhuhur, Piru Bay, Ceram, 128° 8'E, 3° 15'S; H8-9, 20-26 fms., coarse sand, lithothamnion sand rubble, Date coll: 1/6/1970. The largest specimen (KR VI/H3-10) one male of cl:9, cb:10.

*Preliminary remarks.*—Apart from the original of De Haan (1835, not seen) the single accurate description of *integra* is that of Sakai (1939). It could be considered that no accurate illustration of the species exists in the literature at least in regard to the chelipeds, the best being those of Sakai (1939, 1965). A re-examination of the Type specimen or material from Japan would be essential to evaluate the present observations. The only reference in the literature to the size of the species is a male of 18x22.5 given by Sakai (1939), who recorded a total of 16 specimens.

Alcock (1899) quotes: "*K. rastripes* Muller" as a synonym of *integra* and Balss (1922) kept the same standpoint. In fact, the description of Alcock corresponds to *rastripes* and not to *integra*. Some of the specimens of *integra* identified by authors referring to Alcock (1899) could belong to *rastripes*, as is further demonstrated for those of Tweedie (1950).

*Observations.*—The frontal lobes are "shallow bilobate" like indicated by Sakai (1939). The sinus of the supra-orbital border is well marked. The carapace is granular all over, the granules arranged in small transverse ripples at least on the postfrontal and lateral region. The small specimens under 10 are smooth. The dactyli of the pereopods 2-5 are "blade shaped and recurved" as described by Sakai (1939). On the largest male (277), the two chelipeds are clearly unequal, and with a different shape. On the major cheliped the two fingers are shorter, the palm is higher than on the minor; on the major cheliped the palm is clearly longer than on the minor. Sakai (1939) writes: 'Chelipeds are subequal in size but usually unequal in the shape of the fingers . . . the fingers of one

cheliped are very often longer than those of the opposite cheliped; in a very young specimen, the movable finger is usually very much more incurved inward than in the adult."

On a smaller male (275) of 10x11 the two chelipeds also are clearly unequal and very like the large specimen; the female of the same series (275) is damaged and has only one cheliped which has short fingers but is comparatively less swollen and more acutely granular than on the male. Another small male (the largest of the material from the Mariel King Mem. Exp.) has the chelipeds which seem to agree with the characters of the young mentioned by Sakai (1939): the two fingers of the two chelipeds being "more incurved inward". On the large specimens the black pigment of the fixed finger extends to half the height of the palm on the distal area.

The male pleopod 1 seems to be nearly similar with those illustrated by Sakai (1934, text-fig. 64) and Buitendijk (1960, fig. 1a). However I hold some reserve on the identity of the present material with *integra*.

The species is recorded from Japan (De Haan, Balss, Sakai), China (Gordon), Hawaii (Rathbun), Gilbert Island (Balss) and Sulu Molucca Seas (present record). Milne (1884, p. 235) in recording specimens of *nitida* mentioned that in the British Museum, specimens from Philipines (Cuming collection) probably belongs to *integra*. It is, with *nitida* and *rugulosa*, the most recorded species of *Kraussia*. The specimen (WAM.271-70) from the S. of Cape Poivre is the first record of the species in Australian waters.

#### *Kraussia bongensis* nov. sp.

(Figs. 19, 20, 23J, 24)

Type specimen: Western Australian Museum.

Type locality: Tawitawi Bay, Sulu Archipelago.

*Material.*—Holotype (WAM.263-70A) male of cl:20, cb:23; Paratypes, WAM.263-70B, male of cl:15, cb:17; WAM.263-70C, male of cl:14, cb:15, Loc: about 9 miles 130° from Bongae Light, Tawitawi Bay, Sulu Arch., Coll: B. R. Wilson on "Pele", Date coll: 29/2/1964. Other specimens of the same loc: 2 males and 1 female, the largest of cl:9.5, cb:11.

*Diagnosis.*—(Holotype). Carapace dorsally convex with fine small granular transverse ripples all over. Front bilobate, anterior margin of lateral frontal lobes straight, no trace of antennal sulcus. Antero-lateral border with a feeble concavity behind external orbital angle and posteriorly a feeble notch. Two chelipeds unequal and differently shaped. Major cheliped with palm higher and longer than that of minor cheliped. Length of fixed finger clearly more than one-third of height of palm on major cheliped, and clearly less on minor cheliped. Outer surface of both chelipeds similarly covered with salient granular transverse ripples and ornamented on distal part with black colour of fixed finger extending near upper border of palm. Dactyli of pereopods 2-4 sickle-shaped with anterior border concave without granules save on a very short proximal flat-

tening; anterior border of pereopod 5 entirely granular. Male pleopod with apex forming a lamellar broadening lobe with round distal margin; some subdistal long acicular setae and some stout pre-apical spines.

*Observations.*—Only on the holotype is the black colour of the palm strongly marked. The male pleopod of the largest paratype has a larger number of subdistal setae and the apical lobe slightly differently shaped. On the smallest male the apical lobe is only developed as a straight small tongue not significantly broadening distally.

The male pleopod provides the most significant discrepancy between *bongensis* and *integra*. In addition, *bongensis* differs from *integra* by: (1) the frontal lobe with anterior margin straight instead of sinuous and median sinus closer.—(2) a marked small concavity immediately behind the extraorbital angle.—(3) a less subquadrate outline of the carapace border and its dorsal surface more convex.—(4) the fingers of both chelipeds which are more incurved with a wider gap.—(5) the black colour of the palm extending higher.

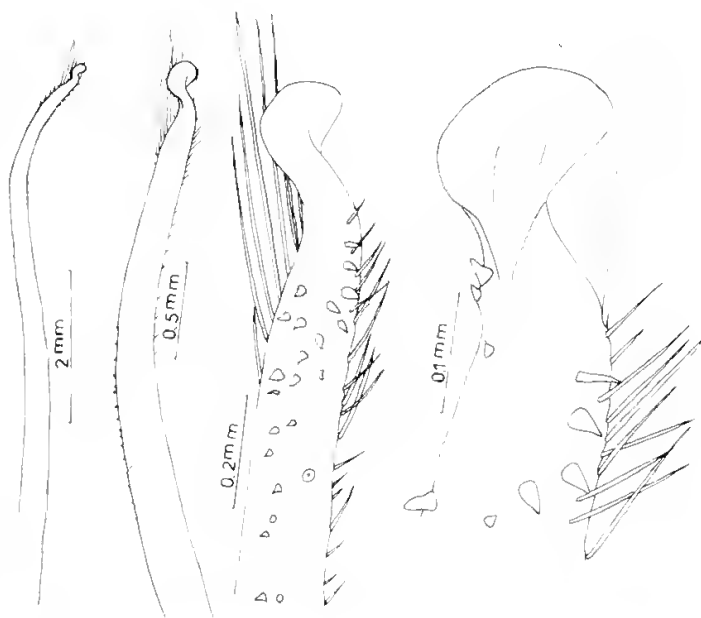


Figure 19.—Male pleopod 1 of *K. bongensis*. WAM 263-70 of cl:20, cb:23.

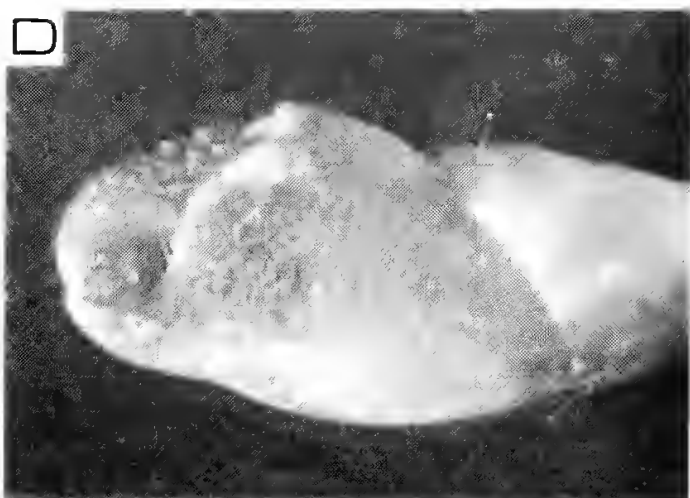
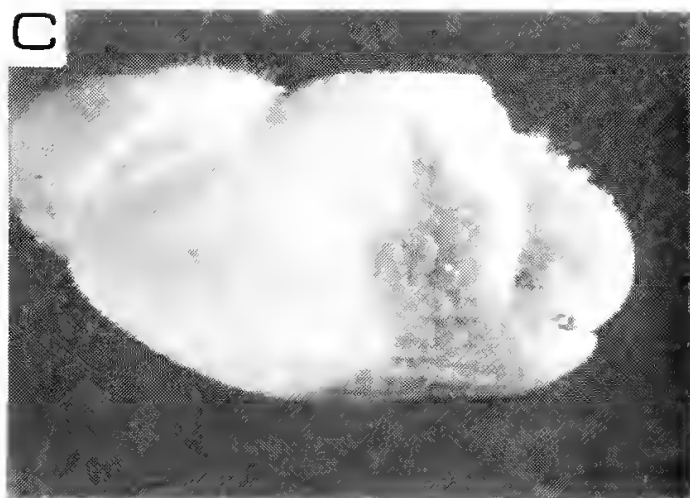
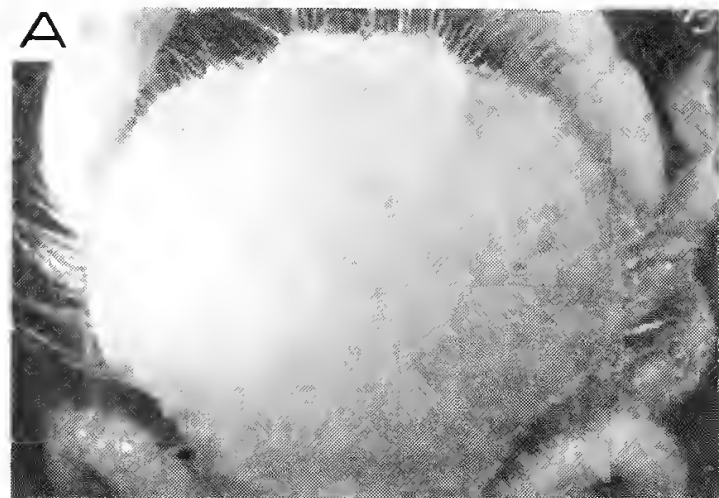


Figure 20.—*Kraussia bongensis*, WAM 263-70, male of cl:20, cb:23. A, dorsal view.—B, pereopods 4, 5.—C, right cheliped.—D, left cheliped.

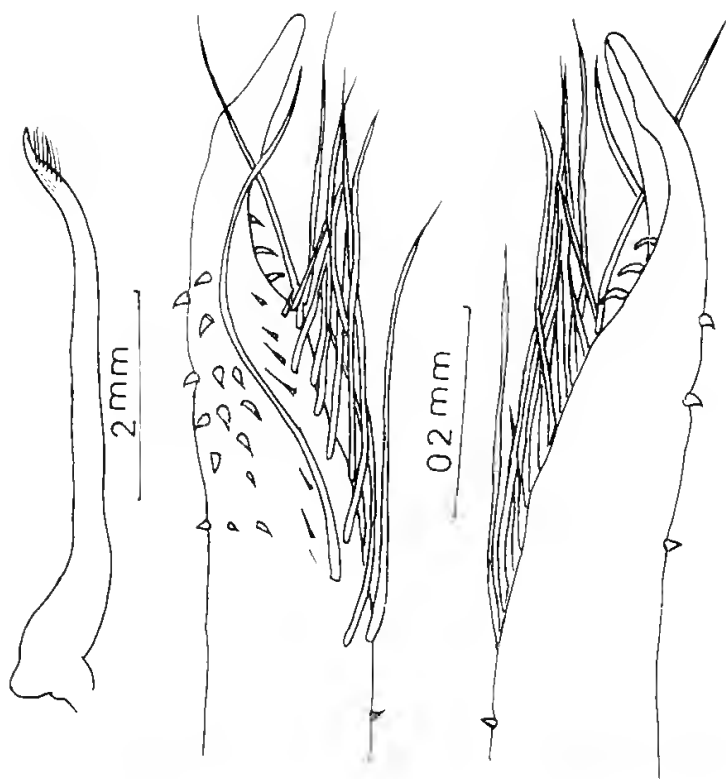


Figure 21.—Male pleopod 1 of *K. rastripes*, NMS.1969. 11.20.4 of cl:9, cb:10.

Measurements taken on the carapace of largest males of *integra* (1), *bongensis* (2) and *rastripes* (3) give the following ratios:

	1	2	3
carapace breadth/carapace length	1.13	1.14	1.14
frontal breadth/carapace length	0.33	0.33	0.44
frontal breadth/carapace breadth	0.29	0.29	0.38
fronto-orbital breadth/carapace breadth	0.54	0.50	0.58

This demonstrates that only *rastripes* has a front clearly broader than *bongensis* and *integra*. The comparison of the present ratio with those given before for the *aff. nitida-marquesa* group confirm that the specimen of *marquesa* from Puerto Galera has a carapace broader than any other.

### *Kraussia rastripes* Muller 1887

(Figs. 21, 22, 23K)

*Kraussia rastripes*, Muller, 1887, p. 480, pl. 4, fig. 5.—Borradaile, 1900, p. 576.—Balss, 1938, p. 28, fig. 13.

*Kraussia integra*, Alcock, 1899, p. 97.—Tweedie, 1950, p. 108. Not *integra* (De Haan).

Type locality: Ceylon (Trincomale).

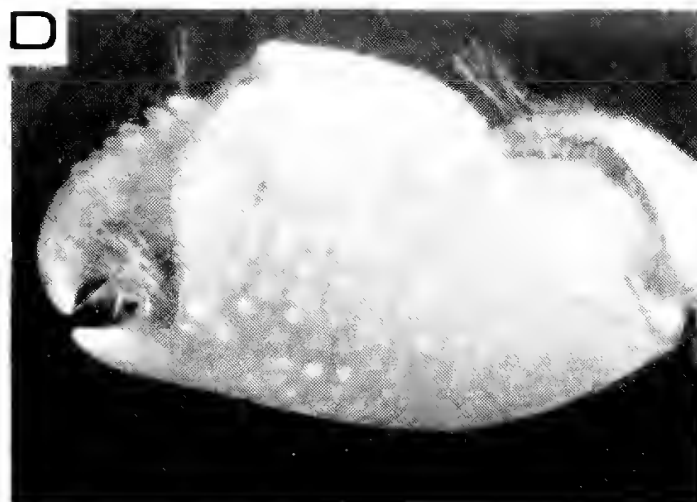
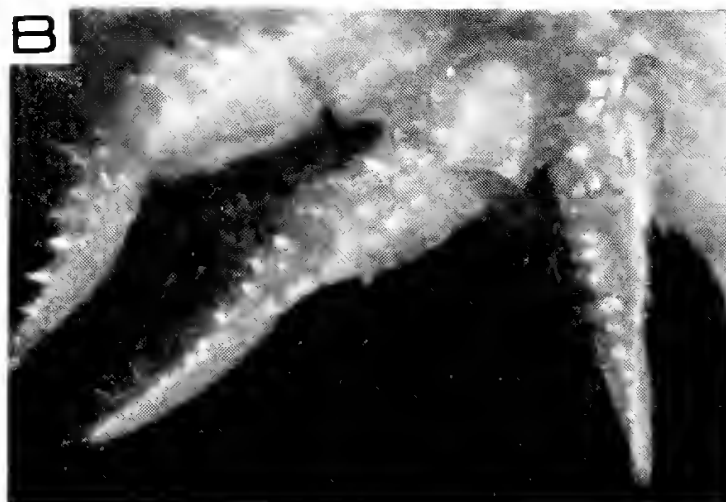
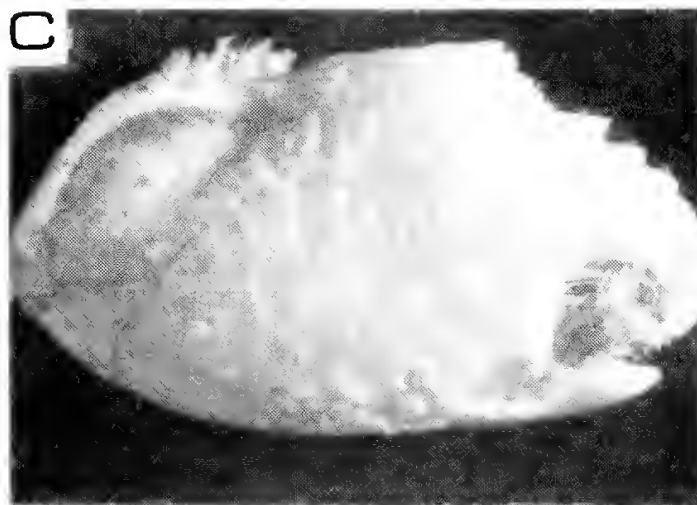
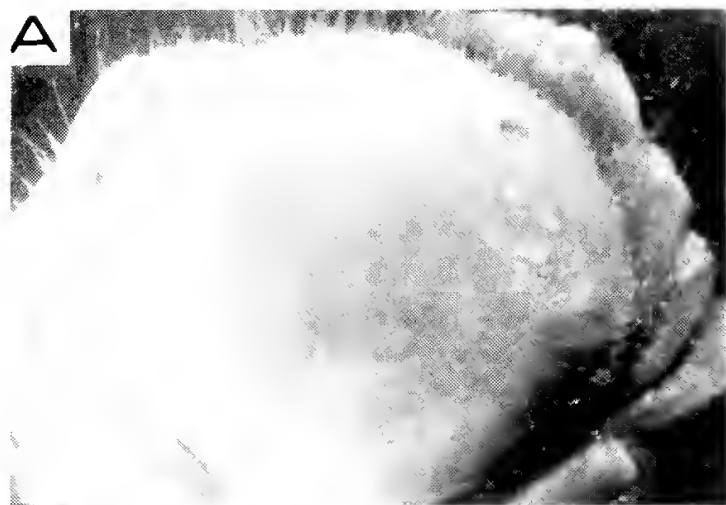


Figure 22.—*Kraussia rastripes*, NMS.1969 11.20.4, female of cl:10, cb:12.40. A, dorsal view.—B, pericopods 3, 4.—C, right cheliped.—D, left cheliped.



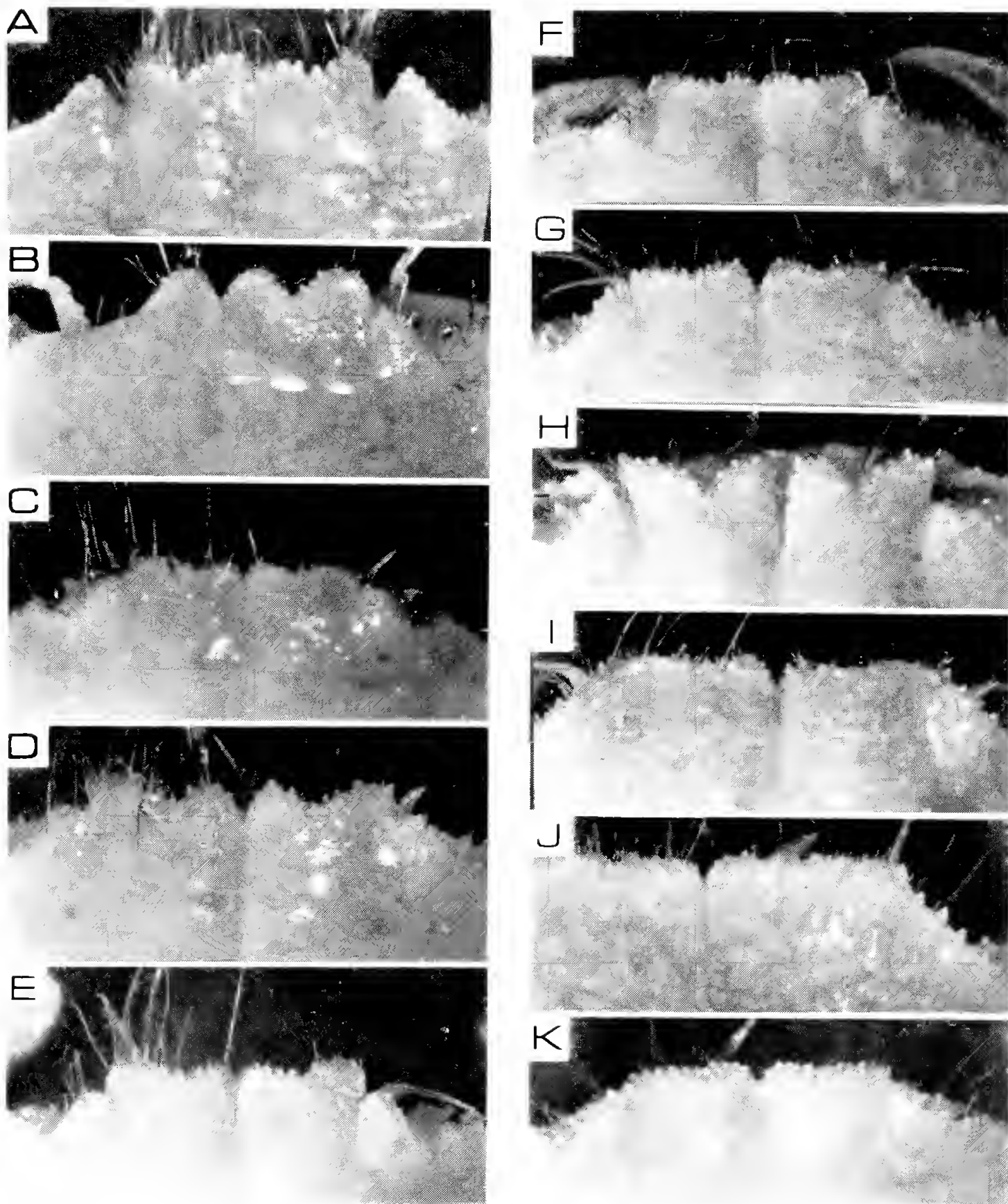


Figure 23.—Frontal border of *Kraussia*: A, *rugulosa*.—B, *quadriceps*.—C, *wilsoni*.—D, *pelsartensis*.—E, *roycei*.—F, *aff. nitida*.—G, *H. marquesa*.—I, *integra*.—J, *bongensis*.—K, *rastripes*. Save for H, male of cl:15.3, cb:18.6 of *marquesa*; all specimens are those illustrated in the previous photographs. All photographs with magnification approximately  $\times 10$ .

*Material*.—NMS.1969.11.20.4, male of cl:9, cb:10; NMS.1969.10.10.4, female of cl:10.8, cb:12.40; NMS.1969.10.10.5, female a little smaller, Loc: Cocos Keeling, Coll. Gibson Hill 1941, Det: as *integra*? by Tweedie, 1950, p. 108.

*Remarks*.—Tweedie (1950) expressed reserve in his identification by placing a ? on the label of the jar; the reserve is not indicated on his paper. The specimen agrees accurately with the description of Alcock (1899) for *nitida* but clearly differs from *integra*. Tweedie (1950), referring for his identification as *integra* to Balss (1938), who does not give any illustration nor any comments on *integra*, was probably referring to the description of Alcock (1899).

Muller (1886) mentions the close relation between his species and *integra* but among the characters of *rastripes* he states that the pereopods 2-5 have on the anterior border of the propodi two or three rows and on that of the dactyli one row of acute tubercle-like saw-teeth (Sagezähne). In the description of *integra* by Alcock (1899) the dorsal surface of the dactyli of ambulatory legs "abundantly and elegantly denticulate" correspond to *rastripes* and not to *integra*, which according to Sakai (1939) has those dactyli "blade shaped and recurved".

The name *rastripes* given to a single male of 13 x 15 has been correctly used by Borradaile (1900) for a female from Rotuma, and by Balss (1938), who examined 4 females and 1 male from the Hamburg Museum and one female from the Berlin Museum but gave the size of only one female of 12 x 14. I correct as *rastripes* the identifications of the *integra* specimens of Alcock (1899) and Tweedie (1950).

*Observations*.—The species can be identified at first view by its subcircular carapace ("Panzer subcylindric", Muller) and strongly denticulate ambulatory legs. The material of Tweedie (1950) was examined and found in full agreement with the descriptions and illustrations of Muller (1886) and Balss (1938). *K. rastripes* differs from *integra* and *bongensis* by: (1) the dorsal surface of the carapace more convex and nearly smooth.—(2) the frontal border less salient beyond the orbit and forming a hemispherical curve with the anterolateral border, which are without indication of any notch.—(3) the absence of sinus on the upper orbital border.—(4) both chelipeds equal and identically shaped: the length and height of the palm, the length and shape of the fingers are the same in the two chelipeds.—(5) the palm of the cheliped higher with granules larger but less numerous and more separated; similarly the granules in the dactyli are larger and more separated.—(6) the anterior border of the dactyli of the pereopod 2-5 nearly straight, all along flattened with on each side of the flattening a row of acute teeth.—(7) the male pleopod.

As indicated before in the observations on *bongensis*, also the front of *rastripes* is broader than on these two species.

*K. rastripes* is recorded from Ceylon (Muller), Rotuma (Borradaile), Gilbert Island, Pulau Island, Carolines Island, New Guinea (Balss), Andamans (Alcock), Cocos Keeling Island (Tweedie).

## Remarks on the ecology, the ethology and the relationship of *Kraussia*

I myself have never seen a living specimen of *Kraussia*; the present remarks only refer for ecology to the data of the present collection and some few authors; for the ethology to personal observations made on other groups of Brachyura.

The species of *Kraussia* live on bottom of coarse sand around the rocky and coral area extending from the shores to the depth of 100m. They are digging crabs like the other Corystidae, the Gymnopleura, some Oxystomata, some Xanthidae, Goneplacidae and Pinnotheridae. Observations on the behaviour of these forms and on the ecological condition of their habitat (nature of the bottom, composition of the sand or mud by granulometry) will help to understand the function of their morphological structures.

The vaulted carapace of *Kraussia* with the pereopods (when folded) partly fitted below the margins is somewhat similar to that of *Calappa* for example. It suggests that, like *Calappa* when it has dug, *Kraussia* hides its body under the sand in a oblique position, its anterior part at the level of the surface of the sand and the posterior part a little lower.

During the examination of the present material in order to find morphological structure which could provide characters for specific differentiation, I noticed on the ventral side of the posterior half of the lateral border of the carapace of *integra* and *bongensis* a shallow, elongate and smooth depression. Situated between the pterygostomian line and the edge of the border, this structure reminds me of a similar but more developed one which I recently observed on *Guinotellus* Serene 1971, a new genus of Xanthidae. This genus is briefly described from type material consisting of only one carapace without pereopod which was then the only available material; its relationship to *Hypocolpus* and *Euxanthus* is briefly mentioned by Serene (1971).

The comparison of *Kraussia* (mainly *integra*) with large specimens of *Guinotellus* in good condition presently in hand demonstrates several close relationships between the two genera, and suggest that *Guinotellus* could be a morphological link between the Euxanthoidea (*Hypocolpus-Euxanthus*) and the Thididae (*Kraussia*), two groups with probably the same ethology.

The relationship between *Kraussia*, *Guinotellus* and *Euxanthus* are supported by several morphological structures, such as the lateral border of the carapace vaulted with the ambulatory legs when folded at least partly concealed; the chelipeds strongly fitted against the pterygostomian region; the third maxilliped, sternum and abdomen narrow; and the male pleopod 1 elongate and slim. But *Euxanthus* and *Guinotellus* clearly differ from *Kraussia* by the orbito-antennal region and the presence at the anterior limit of the buccal cavern of a small but clearly marked margin, which does not exist on *Kraussia*.

Other common characters like the occasional presence on the carapace of small, flattened (squamiform) granules arranged in transverse



lines (like ripples) seems to be related to the ecology and ethology of the forms. It is perhaps also the case for the indication on *Kraussia integra* and *bongensis* of a shallow ventral cavity under the margin of the posterior part of the lateral border, which on *Guinotellus* are so well developed in the anterior part.

The function of these cavities is probably related to the water current running in the vault organized under the lateral margin of the carapace. Similarly, the notches of the lateral margins of *Kraussia* could be related to the passage (output or input) of such a water current. Without speculating further, I summarize my observations by bringing together the illustrations (Fig. 24) of the ventral side of the lateral border of *Kraussia bongensis* and of *Guinotellus melvillensis* Serene 1971.

### Acknowledgements

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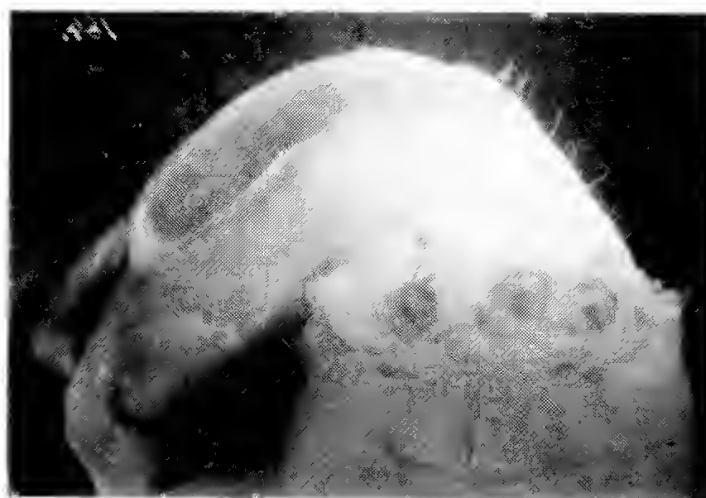
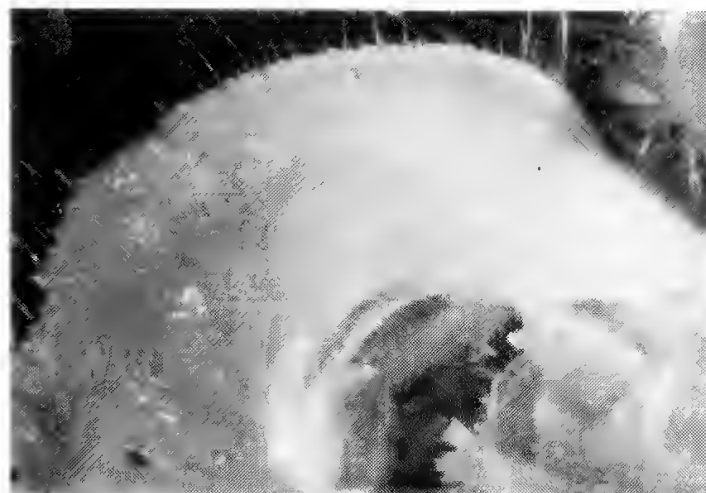


Figure 24.—Above, *Kraussia bongensis*, ventral side of the lateral border of carapace. Below, *Guinotellus melvillensis*, ventral side of the lateral border of carapace with cavity of the subhepatic region.

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## 7.—An archaeological site in the Chichester Range, Western Australia: preliminary account

by C. E. Dortch\*

*Manuscript received 19 October, 1971; accepted 20 June, 1972.*

### Abstract

A rich archaeological site on a re-entrant in the Chichester Range, Western Australia was examined. Some Aboriginal stone artifacts were found in the dry bed of the water course, others on the surface of, and *in situ* within an adjoining alluvial terrace, and others on higher ground above the terrace. The artifactual material, which consists largely of blades and points of the "leilira" type, and its provenance are briefly discussed. Technological and morphological similarities which some of these artifacts have with analogous Levallois forms are noted.

### Introduction

In 1967 M. G. Ridpath of the CSIRO Division of Wildlife Research discovered a rich archaeological site on the southern slope of the Chichester Range about 220 km. south of Port Hedland (Figure 1). Ridpath and his wife collected a number of stone artifacts from the surface and sent them with a description of the site and its location to the Western Australian Museum. He later informed J. Bywater and J. Wombey, also of the CSIRO Division of Wildlife Research, of the site's location. In 1970 Bywater and Wombey collected artifacts from this site and found another site on the Cockeraga River on the opposite slope of the Chichester Range 10 km. to the north. They presented collections from both sites to the Western Australian Museum in 1970. In April, 1971, while en route to East Kimberley, the writer, with W. Dix and M. Thompson of the Western Australian Museum, examined the site discovered by Ridpath and briefly visited the one on the Cockeraga River. The following report is based on their findings at the former site.

The stone artifacts collected from both sites at various times are listed in the Western Australian Museum registry as follows:

M. G. Ridpath Collection—A16643.

J. Bywater and J. Wombey Collection—A21966, A21881.

W. Dix, C. Dortch and M. Thompson Collection—B1001-B1003.

### The site and its locality

The site is found on a shallow re-entrant in the hills of the Chichester Range about 6 km. south of the watershed. Its main feature is a *Triodia* covered alluvial terrace on the west bank of the water course. The re-entrant is one of a parallel series of water courses which rise in the Chichester Range and are tributary to the Fortescue River. The river, in this area roughly 15 km. south of the range and running parallel to it, has an underground flow as do the lower reaches of its tributaries. The water course on which the site is located is about 30 m. wide. At the time the site was visited it consisted only of a dry braided bed of sands and gravels, although a large pool was found a few hundred m. downstream.

Artifacts made of black stone are scattered over the surface of the alluvial terrace on the west side of the water course as well as in the stream bed itself. Higher ground on the west side, which may be an older terrace, is also covered with artifacts made of the same stone. Very few artifacts were found on the east side of the water course, which at this point consists of sandy hummocks covered with *Triodia* and small eroded depressions.

Artifacts were found *in situ* in the vertical face of the alluvial terrace on the west side of the water course (Figure 2). The terrace, as seen in section, consists of reddish gritty earth interspersed with imbricated bands of sub-angular and angular fragments of stone and river pebbles. The upper part of the deposit is slightly weathered. The three artifacts found *in situ* were horizontally bedded, and one of them is imbricated with sub-angular fragments of stone (Figure 3). The artifact seen in Figure 3 is drawn in Figure 4A.

From their rolled condition and position within the alluvial deposit, it is apparent that the artifacts found *in situ* are derived. All of the artifacts found on the surface of the terrace as well as in the bottom of the torrent bed are rolled to a greater or lesser degree. The presence of rolled artifacts on the surface of the terrace, others *in situ* within the terrace, and still more lying on the bottom of the stream, suggests that re-sorting of the artifact-bearing gravels has taken place. The presence of the artifacts in the bed of the stream further suggests that the terrace is being seasonally eroded

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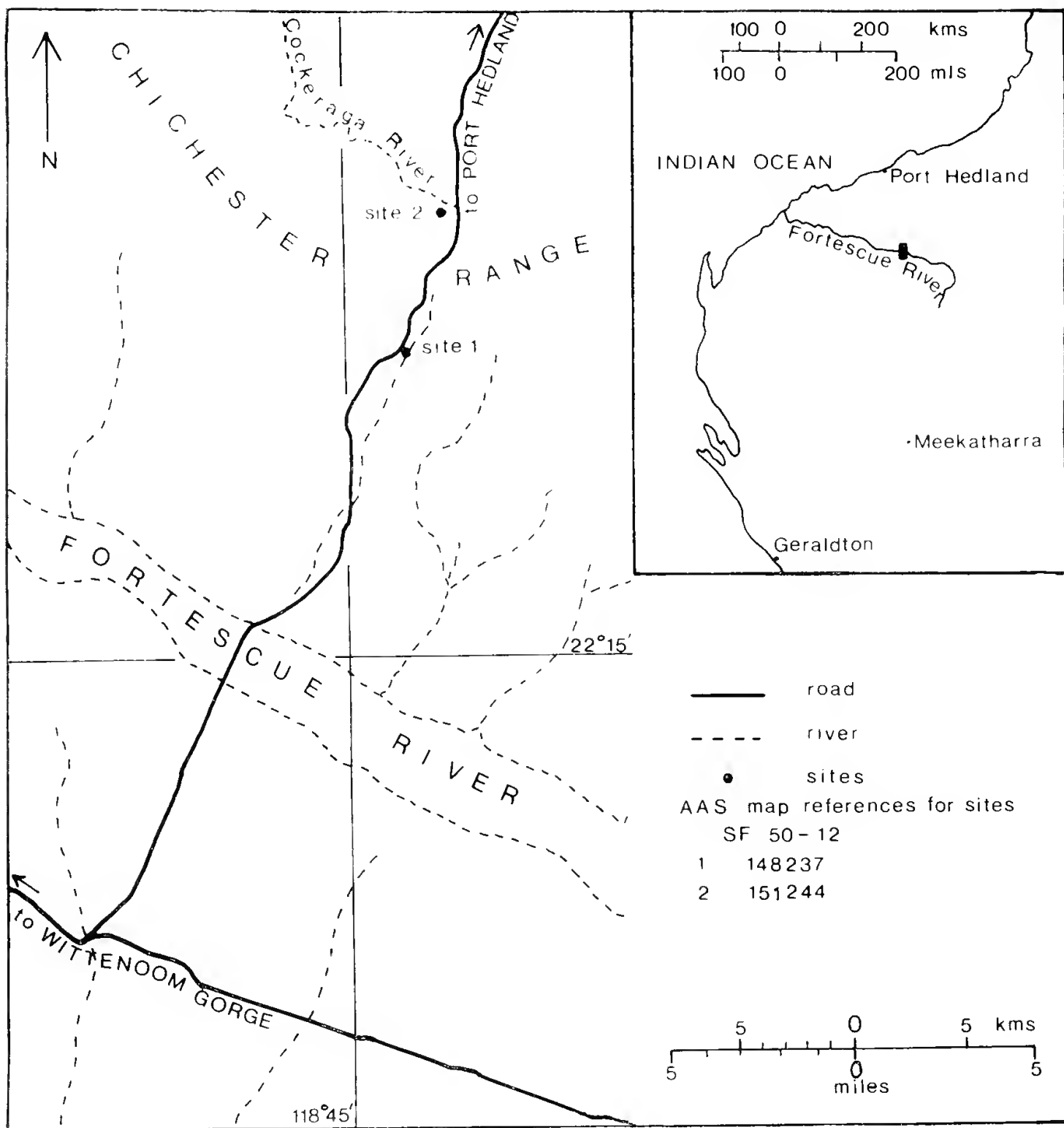


Figure 1.—Sketch map showing location of Chichester Range Sites Nos. 1 and 2.

at present. However, the weathered surface of the terrace as well as its grass cover show that it has been in position for some time.

The terrace extends 20-30 m. back from the present course of the stream. Its full length has not been determined; the part examined extended over 100 m. in length. No excavation of the terrace was carried out, nor was there time available to make a scale drawing of its section.

### The artifacts

Nearly all of the artifacts are made of a black sedimentary stone which R. Peers of the Geological Survey of W.A. has identified as an extremely fine-grained cherty siltstone (personal communication 28th July, 1971). Abundant nodules and fragments of this stone were found in the gravels of the terrace and in the bed of the water course. They are even more abundant at the second site on the Cockeraga River, where the stone occurs in a rich outcrop.

The rolling or natural edge damage on the edges of nearly all of the artifacts in this collection is almost indistinguishable from retouch; that is, none is rolled to such an extent that the edge damage has gone past the critical flaking angle at which retouch becomes extremely difficult (Wymer, 1968, p. 14). However, these pieces are considered to be rolled and not heavily utilized or retouched for three reasons. First, nearly all of the artifacts are indiscriminately chipped or damaged along their peripheries and on both faces. This is a feature typical of rolled assemblages. Secondly, the flake scars in question are often of a fresher patination than the rest of the piece, indicating that a considerable period of time elapsed between the manufacture of the artifact and the time its edges were damaged. A third reason is the provenance of the artifacts. Many are located in the gravelly bed of an active water course; three specimens are *in situ* within an alluvial terrace, one of them (Figure 4A) being imbricated with the alluvial gravel (Figure 3). These then must be derived and almost certainly rolled, even though the larger group of artifacts, those which were found lying on the terrace's surface and on higher ground above the terrace, could be the remains of a camp. The rolled condition of the artifacts from the terrace and the higher ground seems to indicate, however, that they are derived like the others. On the other hand, some of the artifacts (e.g. Figure 5B) have been definitely retouched, and it is probable that in many cases retouched or utilized edges have been obliterated or made unrecognizable by rolling.

No attempt is made here to give a quantitative assessment of the artifactual material as none of the three collections at the site is the result of systematic sampling and because the assemblage is derived. The total collection of 453 pieces shows a marked homogeneity because nearly all of the specimens are made of the same kind of stone and because of the large numbers of points and blades of the "leilira"

type. Although a detailed typological and technological description will have to wait until more information is available, the following brief outline should give some idea as to the nature of the collection.

### Points and blades

Large, finely made pointed blades of the "leilira" type are the dominant tool type among the collection of artifacts made by the three different parties which have visited the site. These implements form a continuum which extends from broad triangular points (Figure 4D), through intermediate forms (Figure 4F), to elongated pointed blades (Figures 4B and 4C). There are also numbers of non-pointed blades (Figure 4E), which, according to traditional classification (e.g. McCarthy, 1967, p. 32), should be included under the "leilira" type. The pointed blades (or "points") have been manufactured by the same form of prepared core technique which has been described by Roth (1904, pp. 16-17) and Spencer and Gillen (1904, pp. 641-648). In brief this is a method of blade or point production in which two or more preparatory blades or flakes are removed in such a way as to cause the projected blade to have more or less convergent edges and in most cases a pointed distal end.



Figure 2.—Alluvial terrace at Site No. 1 showing artifacts *in situ*. The two artifacts are registered B1002 and B1003 in the Western Australian Museum collection.



There are a few blades, including that one found *in situ* within the terrace (Figure 4A), which are made by a different method of prepared core technique from that described above. That is, the shape of the blade is pre-determined by centripetal flaking of the face of the core before it is struck off. Other blades have dorsal faces with bipolar flake scars which show that double-ended cores were being used.

#### Flakes

Most of these are thick, broad specimens with broad butts and wide angles between the plane of the butt and that of the bulbar face. There are a few flakes with centripetal faceting on their dorsal faces, which shows they were made by the second form of prepared core technique above. An illustrated specimen of one of these (Figure 5A) appears to have been retouched or notched prior to its being rolled. There are also many irregular flakes and fragments of flakes which could result from stone nodules and pebbles being roughly shaped up or tested by the stone workers.

#### Scrapers and other Tools

These are not common in this assemblage. Most of the retouched pieces consist of flake scrapers or small irregular adze-like tools. Several denticulated or notched pieces, a burin and an alternately retouched burin-like tool were also found. One of the more interesting pieces is a double-truncated flake which closely resembles the trapeze form of geometric microlith (Figure 5B). Because of its large size, and because it is abruptly retouched only at each extremity and not along one lateral edge as well, it probably should not be considered as a geometric microlith but as a small double-ended scraping or adzing tool. No geometric microliths or backed blades or points have yet been found at the site.

#### Cores

The few cores which have been recovered from the site include those used to obtain pointed blades or points (Figures 5D and 5E). The flake



Figure 3.—Close-up photograph of artifact (B1002) *in situ* within the alluvial deposit and slightly imbricated with sub-angular stones.



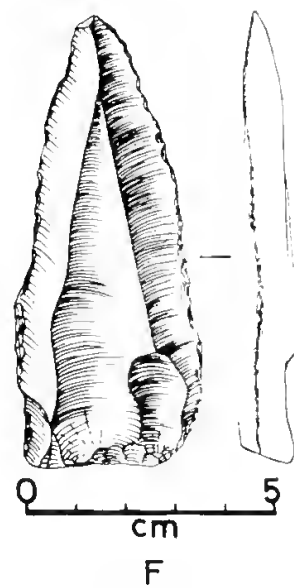
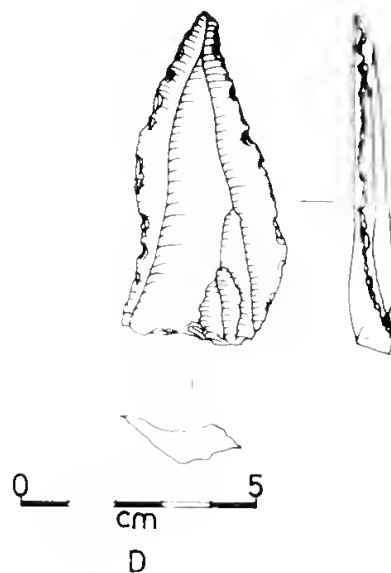
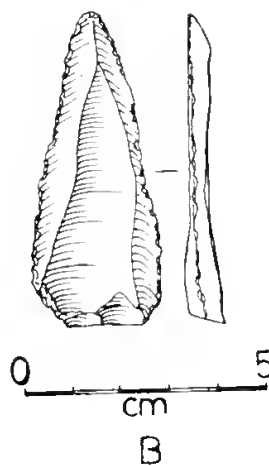
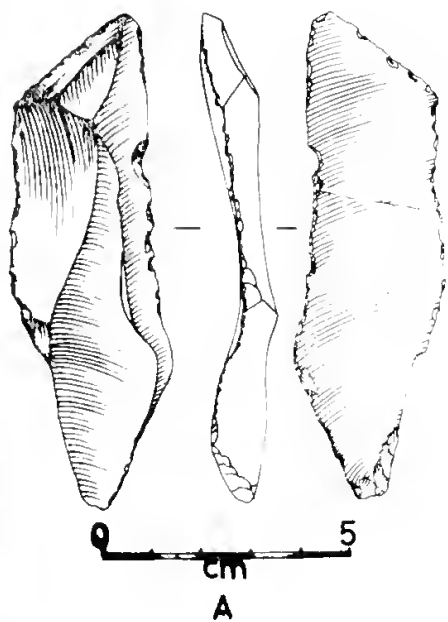


Figure 4.—Blades and points. Figure 4A shows the same artifact shown in close up in Figure 3.

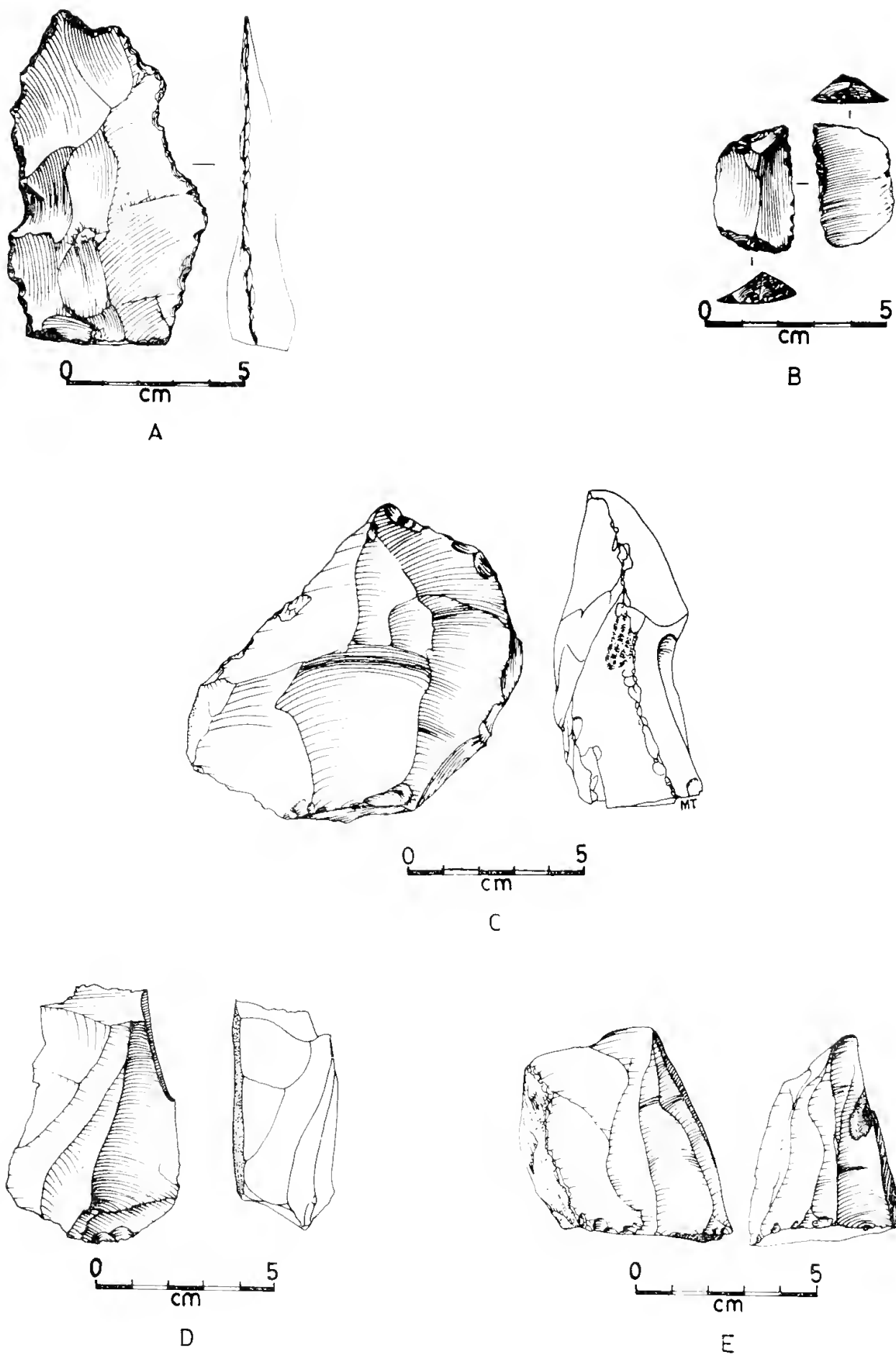


Figure 5.—Flake tools and cores.

cores collected are less typical and some are simply split pebbles from which flakes have been struck at random.

### Discussion

The main purpose here is to note similarities which some of the artifactual material from this site have to analogous forms embodying some of the developed Levallois techniques associated with the industries of the Mousterian complex of Europe, Western Asia and North Africa. First, however, it should be pointed out that there are only three or four cores which substantiate the similarities outlined below. Therefore this comparison must remain tentative until a larger selection of cores from this and similar sites can be examined.

The points illustrated in Figures 4D and 4F are identical in appearance to typical Levallois points, while those in Figures 4B and 4C are strikingly similar to elongated Levallois points. The point core in Figure 5D is very similar, both in appearance and technologically, to a typical Levallois point core. These similarities are best seen by comparing the illustrations here to the type illustrations of Levallois points and point cores in Bordes' classic work "Typologie du Paléolithique ancien et moyen."

In addition the blades and flakes made by the second form of prepared core technique mentioned above have strong resemblances to those made on Levallois cores whose flaking faces have been prepared by centripetal or parallel flaking (see Bordes, 1950; 1961).

The forms of the blade and the flake in Figures 4A and 5A have been pre-determined by centripetal flaking before they were removed from the core. Unfortunately there is only a single core so far recovered from the site which can be associated with this second form of prepared core technique. This specimen (Figure 5C) is similar to a mis-struck Levallois flake core. The face of the core has been prepared by sub-parallel flaking while the last flake removed has hinged out.

Despite the lack of more definite evidence which a large selection of cores would provide, it should be apparent that there is a strong similarity between the two manufacturing techniques here and some of the Levallois techniques. Knowledge of this occurrence at times seems implicit in the Australian literature (e.g. McCarthy, 1967, p. 17). However, it is felt that these similarities should be more fully recognised in Australia and made clear to students elsewhere.

Further work at the site discussed here and a programme of reconnaissance in the Chichester Range and other parts of the Pilbara region should provide additional data to enable this comparison of these manufacturing processes to be extended. More definite evidence has already been recovered in the Ord Valley in East Kimberley, but the data are not yet available for publication.

### Conclusions and recommendations

The finding of artifacts *in situ* within the alluvial terrace and on its surface, on higher ground above the terrace, and in the bed of the water course presents certain problems. For example, one cannot assume that these artifacts have a common origin; they may have been derived from several points upstream at different times. This is one of the reasons why the assemblage is not being dealt with quantitatively here.

Further field work at the site and in the locality should include the following.

1. Stone artifacts from open camp sites on undisturbed ground above the water course should be collected systematically in order to determine the range of artifact types and to gain some idea of their relative frequencies.

2. The length, breadth and thickness of the alluvial terrace should be determined. At least three strips five to ten m. wide each should be laid out at right angles to the water course at points along the terrace where it can be reasonably certain that no collecting has taken place. The strips should each include the higher ground on the west bank, the surface of the terrace and its vertical face, the bed of the water course, and a small part of the east bank. All of the artifacts occurring within each of the strips should be collected and bagged separately according to the features upon or within which they were found. This sampling scheme should provide much more significant data than is presently available.

3. A small pit should be dug at any place along the terrace section where artifacts could be seen *in situ*. The main purposes of this trench would be to determine the feasibility of extended excavation of the terrace and to obtain a radio-carbon sample which could be related to the artifacts within the deposit. Depending upon its breadth and depth the test pit could provide a great deal of information on the composition of the terrace and its relation to the present stream bed.

Future field work should provide more points, flakes and cores associated with the two forms of prepared core technique above. The evident similarities of these manufacturing processes to analogous Levallois techniques are regarded at present as an extremely interesting case of independent invention, and one which invites speculation on the evolution of stone working techniques in general.

### Acknowledgements

The writer wishes to acknowledge the help given by several members of the Western Australian Museum staff in the completion of this report: Mrs Pearl Kaill, who advised on geomorphological aspects of the site and also drew

the sketch map; M. Thompson, who did most of the line drawing illustrations; W. Dix, for his advice in the field and his photographs of the alluvial terrace; Mrs Vera MacKaay, for developing the photographs; Mrs Sue Dyer, for typing the manuscript and I. M. Crawford and D. Merrilees for advice on the text. The writer is grateful to Miss Robin Peers of the Geological Survey of Western Australia for her petrological analysis of the stone of which the artifacts are made and to M. Newcomer of the University of London for his advice on stone artifact technology.

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## 8.—The genus *Morethia* (Lacertilia, Scincidae) in Western Australia

by G. M. Storr\*

*Manuscript received 21 March, 1972; accepted 18 July, 1972.*

### Abstract

The seven species and subspecies of *Morethia* occurring in Western Australia are described and keyed, viz. *M. taeniopleura ruficauda* (Lucas & Frost), *M. taeniopleura exquisita* subsp. nov., *M. boulengeri* (Ogilby), *M. butleri* (Storr), *M. obscura* sp. nov., *M. lineoocellata* (Duméril & Bibron), and *M. adelaidensis* (Boulenger). Lectotypes are designated for *Morethia anomala* Gray [= *M. lineoocellata*] and for *Ablepharus lineoocellatus adelaidensis* "Peters" [= *M. adelaidensis* (Boulenger)].

### Introduction

Following Boulenger (1887) most authors have placed all the skinks with an immovable transparent eyelid in the genus *Ablepharus*. This reliance on a single character brought together species from different continents with little or nothing else in common (Fuhn 1969a), and it generically separated skinks that were very closely related (Greer 1967).

Fuhn (1969b) has shown that the Australian skinks with ablepharic eyes fall into about nine groups, including the genus *Morethia*. For the skull morphology of *Morethia* and other ablepharic skinks, the reader is referred to Dr. Fuhn's papers.

This revision of the western species of *Morethia* has been greatly aided by Dr. Michael Smyth's concurrent study of the South Australian species, all of which extend into Western Australia. I am indebted to Mr. A. F. Stimson of the British Museum for the loan of type specimens.

### Genus *Morethia* Gray

*Morethia* J. E. Gray 1845, "Catalogue of the specimens of lizard in the collection of the British Museum", p. 65.

*Type-species* (by monotypy).—*Morethia anomala* Gray (ibid.).

*Diagnosis*.—Small pentadactyl skinks with lower eyelid immovable and transparent; frontoparietals and interparietal normally fused into a single quadrilateral shield; supranasal and postnasal present (except in *lineoocellata*, where they are often fused to nasal). Distinguishable from *Cryptoblepharus* by frontal much larger than (rather than subequal with) prefrontals and by palpebral disc not completely surrounded by granules.

*Distribution*.—Throughout most of Australia.

*Characters* (additional to those in diagnosis).—Frontonasal in broad contact with rostral. Prefrontals usually separated, rarely forming a short suture. Frontal in contact with first 2 of 4 supraoculars. Usually one pair of nuchals. Ear lobules present (except in some races of *taeniopleura*), first (i.e. dorsalmost) usually largest. Upper labials normally 7, third-last largest and subocular.

*Material*.—*M. t. taeniopleura* (5 specimens), *t. ruficauda* (40), *t. exquisita* (40), *boulengeri* (12), *butleri* (28), *obscura* (180), *lineoocellata* (115), *adelaidensis* (71). Apart from type material borrowed from the British Museum, all specimens cited in the text are in the Western Australian Museum.

### Key

1. Back and sides glossy black with 2 or 3 prominent white stripes ..... 2  
Back and sides olive grey, olive brown or rufous brown, with or without black and white stripes, ocelli and spots ..... 3
2. No vertebral stripe; usually no ear lobules ..... *taeniopleura ruficauda*  
A white vertebral stripe and small ear lobules usually present ..... *taeniopleura exquisita*
3. Subdigital lamellae obtusely keeled or smooth ..... 4  
Subdigital lamellae sharply keeled ..... 6
4. Fourth supraciliary not smaller than third ..... 5  
Fourth supraciliary much smaller than third ..... *boulengeri*
5. Fifth supraciliary (like third and fourth) penetrating deeply between supraoculars; supranasal often fused to nasal; dorsal ocelli and midlateral white stripe usually well developed ..... *lineoocellata*  
Fifth supraciliary not penetrating deeply between supraoculars; supranasal always separate from nasal; dorsal ocelli and midlateral white stripe absent or weakly developed ..... *obscura*
6. Supraciliaries normally 6 and forming straight-sided series ..... *butleri*  
Supraciliaries normally 5, last three penetrating deeply between supraoculars ..... *adelaidensis*

\*Western Australian Museum, Perth, Western Australia.

### ***Morethia taeniopleura ruficauda***

*Ablepharus lineo-ocellatus* var. *ruficaudus* Lucas & Frost, 1895, Proc. Roy. Soc. Vic. (new ser.) 7: 269. Goyder River or Bagots Creek, Northern Territory (fide Coventry 1970: 119).

**Diagnosis.**—The species *taeniopleura* is distinguishable from other *Morethia* by its black or blackish, unspotted back and somewhat depressed head. The subspecies *M. t. ruficauda* is distinguishable from *M. t. taeniopleura* (Peters) of eastern Queensland by its four (rather than five) supraciliaries; subdigital lamellae obtusely keeled or narrowly callose (rather than smooth or broadly callose); and more strongly developed dorsolateral stripe

(silvery white, rather than pale brown; as wide or nearly as wide as pale midlateral stripe, rather than much narrower; and extending forward beyond supraciliaries).

**Distribution.**—Kimberley Division and north coast of North-West Division southwest to the De Grey. Extralimital in Northern Territory (except far north, where it is replaced by an undescribed race).

**Description.**—Snout-vent length (mm): 18-36 (30). Tail (% SVL): 128-189 (154).

Supranasal always and postnasal almost always present, though occasionally fused to each other or merely separated by a shallow groove.

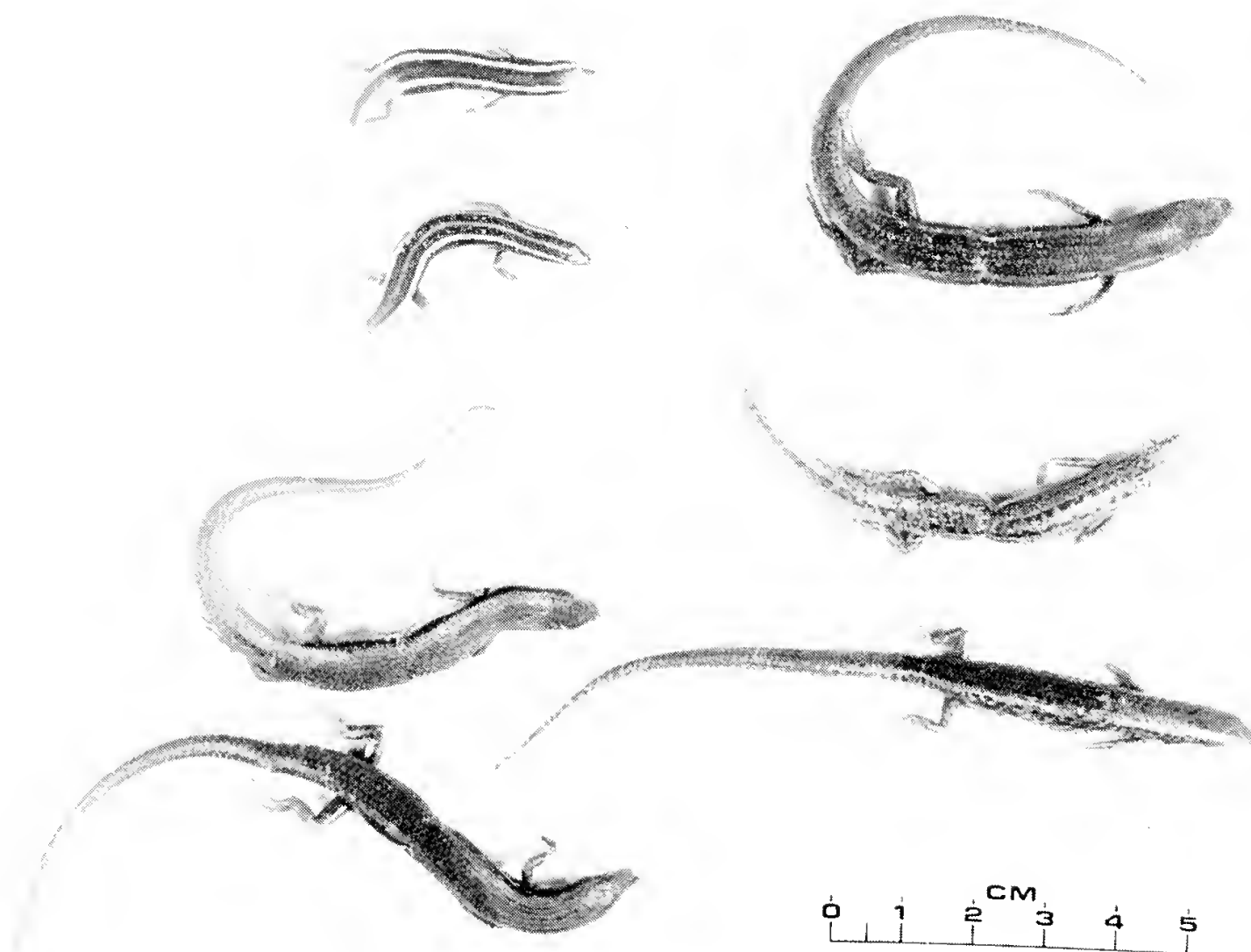


Figure 1.—Photograph of species and subspecies of *Morethia* occurring in Western Australia. Left, top to bottom: *taeniopleura ruficauda*, *taeniopleura exquisita*, *boulengeri*, and *butleri*. Right, top to bottom: *obscura*, *lineoocellata*, and *adelaidensis*.



Supraciliaries 4, second and third largest and penetrating deeply between supraoculars, third and fourth forming a roughly linear junction with supraoculars. Ear lobules usually absent (three specimens have 2 or 3 small obtuse lobules). Midbody scale rows 26-30 (mostly 26 or 28, mean 27.4). Lamellae under fourth toe 16-21 (mean 18.6), narrowly callose or obtusely keeled.

Head, back and sides glossy black. Tail red. White dorsolateral stripe often extending forward to snout and meeting its opposite number. White midlateral stripe narrowly or not edged below with black.

**Material.**—**Kimberley Division** (W.A.): Kalumburu (27972-8, 40497, 40951-6), Wotjulum (11213-7), Derby (20274-82, 20342), 12 mi. S of Derby (23009-10), Geikie Gorge (32153), Broome (27971, 40957), Frazier Downs (27965). **North-West Division** (W.A.): De Grey Station (2126). **Northern Territory:** Katherine (23162), Wauchope (34637), 26 mi. SW of Wauchope (24323), Dover Hills (40150).

***Morethia taeniopleura exquisita* subsp. nov.**

**Holotype.**—R 37709 in Western Australian Museum, collected by Mr. John Wombey on 16 September 1970 at Tambrey, Western Australia, in 21°37'S, 117°36'E.

**Diagnosis.**—Distinguishable from all other races of *taeniopleura* by whitish vertebral stripe.

**Distribution.**—North-West Division, from Depuch Island and Marble Bar, south to the Cape Range, the middle Gascoyne and the upper Ashburton.

**Description.**—Snout-vent length (mm): 15-45 (31). Tail (% SVL): 155-211 (190).

Supranasal and postnasal always present, though occasionally fused to each other. Supraciliaries normally 4, second and third largest and penetrating deeply between supraoculars, third and fourth forming a roughly linear junction with supraoculars. Ear lobules 0-4, small and obtuse, first usually largest. Midbody scale rows 26-32 (mostly 26 or 28, mean 27.2). Lamellae under fourth toe 17-24 (20.5), broadly callose to finely keeled.

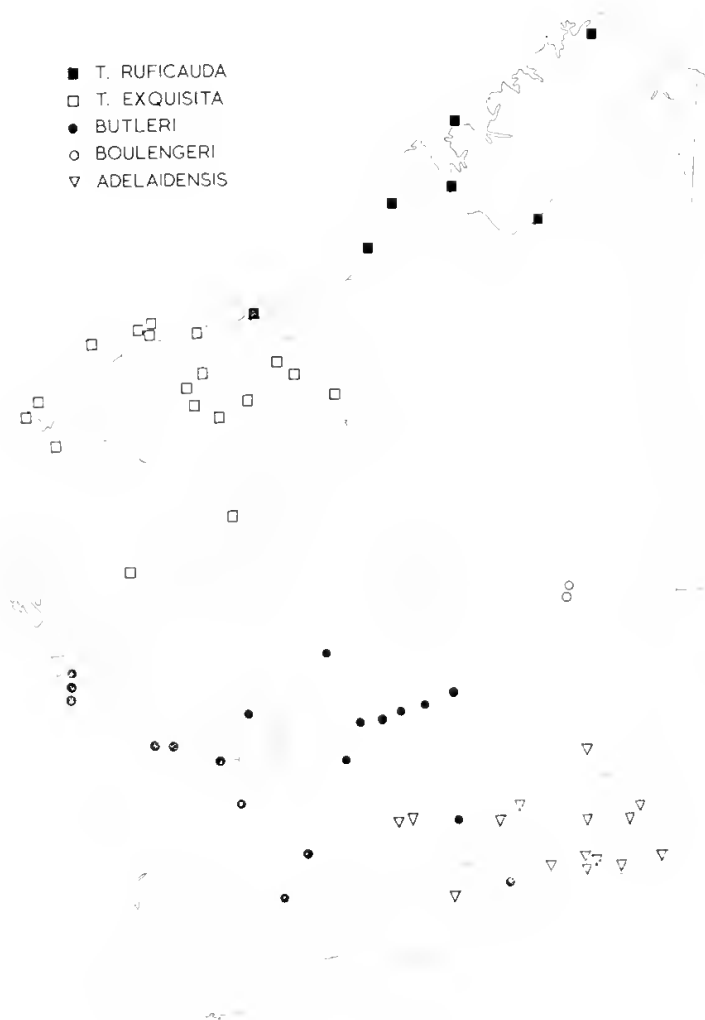


Figure 2.—Map of Western Australia showing location of specimens of *Morethia taeniopleura*, *M. butleri*, *M. boulengeri* and *M. adalaidensis*. Drawn by Margaret H. Shepherd.



Figure 3.—Map of Western Australia showing location of specimens of *Morethia lineocellata* and *M. obscura*. Drawn by Margaret H. Shepherd.

Coloration as in *M. t. ruficauda* with addition of greyish-white vertebral stripe.

**Material.**—**North-West Division** (W.A.): Marble Bar (18403-4); Mt Edgar (18398-402); Skull Springs, Davis River (39051); upper Cockeraga River (36595-6); 9 mi. S of Wittenoom (37088); Asbestos Creek (20015); upper Sherlock River (20014); Depuch Island (14574); Legendre Island (14332, 14360); Dolphin Island (14290-1, 14298, 37292-3); Rosemary Island (37393); Barrow Island (27966-70, 40689-91); Exmouth (31440); Shothole Canyon, Cape Range (18405); Yardie Creek (the watercourse, not the homestead) (21775); Marrilla (5338); Chalk Springs, Ethel River, 30 mi. SE of Mt Vernon (22799-800); Coordewandy (28383-5).

### *Morethia boulengeri*

*Ablepharus boulengeri* J. D. Ogilby, 1890, Rec. Aust. Mus. 1: 10, Cootamundra, N.S.W. (H. J. McCooey).

**Diagnosis.**—Six supraciliaries, first and third largest, last four forming a decreasing series, their junction with supraoculars roughly linear. Further distinguishable from *M. butleri* by smooth or obtusely keeled subdigital lamellae.

**Distribution.**—Far eastern interior of Western Australia (vicinity of Warburton Range), east through South Australia, New South Wales and south Queensland to the western slopes of the Great Dividing Range.

**Description.**—Snout-vent length (mm): 27-50 (40). Tail (% SVL): 137-177 (155).

Supranasal and postnasal always present but either fused to each other or merely separated by shallow groove. Ear lobules 2-4 (usually 2), usually obtuse. Midbody scale rows 30 or 32 (30.7). Lamellae under fourth toe 18-23 (20.0), broadly or narrowly callose.

Back olive green, variably marked with black (small spots or broken lines through middle of scales). Broad black upper lateral stripe. Moderately broad white midlateral stripe.

**Remarks.**—I am grateful to Dr M. Smyth for the two specimens from Salter Springs and for their identification with *boulengeri*, the type of which he has examined.

**Material.**—**Eastern Division** (W.A.): Warburton Mission (22016, 22110-1); Ainslie Gorge (18296). **South Australia**: 116 mi. N of Cook (36656); Emu (36612-3); Leigh Creek (40570); Salter Springs (39795-6). **Queensland**: Alum Rock, near Amiens (18545); Fernvale (18544).

### *Morethia butleri*

*Ablepharus butleri* Storr, 1963, W. Aust. Nat. 9: 46, Leonora, W.A. (G. M. Storr & R. E. Moreau).

**Diagnosis.**—Supraciliaries 6 (rarely 7), first largest, remainder forming a decreasing series, their junction with supraoculars nearly linear. Further distinguishable from *M. boulengeri* by sharply keeled subdigital lamellae.

**Distribution.**—Arid and semiarid parts of southern interior of Western Australia, between

latitudes 27°30' and 32°30'S, west to about the eastern edge of the Wheat Belt, and east to the western edge of the Great Victoria Desert and of the Nullarbor Plain.

**Description.**—Snout-vent length (mm): 25-56 (46). Tail (% SVL): 134-169 (152).

Supranasal and postnasal always present, though often fused to each other or merely separated by a shallow groove. Ear lobules 2-5 (mostly 2 or 3, mean 2.6). Midbody scale rows 26-31 (mostly 28 or 30, mean 28.9). Lamellae under fourth toe 19-27 (22.4).

Head and back dark olive-brown or olive-green, usually unmarked, rarely flecked with black. Tail red in juveniles, brown in adults. Broad black upper lateral stripe and white midlateral stripe variably developed—prominent, indistinct, or absent except anteriorly. Lips dark-spotted.

**Remarks.**—In the far east of its range *butleri* approaches the closely related *boulengeri* in that the supraciliary-supraocular junction is not so linear, though it is the fourth (not the third) supraciliary that tends to protrude. Moreover, *boulengeri* in the far west of its range approaches *butleri* in the number and nature of subdigital lamellae, viz. 20-23 in the vicinity of Warburton Range, against 18-20 elsewhere, and here the subdigital calli are almost narrow enough to be called obtuse keels. However, it would be premature to treat these two skinks as races of one species. More needs to be learnt about their distribution in western South Australia, where Dr Smyth (pers. comm.) has examined a specimen of *butleri* from Ooldea, which is not far south and southeast of *boulengeri* localities.

**Material.**—**South-West Division** (W.A.): Lockwood Spring, Kalbarri National Park (37569); 19 mi. E of Kalbarri (33595); 26 mi. ESE of Kalbarri (33810); 7 mi. E of mouth of Hutt River (28003); 25 mi. E of Morawa (40958); Bonnie Rock (24872); Holt Rock (30941). **Eastern Division** (W.A.): Rothsay State Forest (29606); Youanmi (21164); Kathleen Valley (31672, 39697); Yamarna (18297, 20684); White Cliffs (20665-8); Laverton (18298); Mt Morgans (15686, 18339-44); Leonora (20615); Menzies (18324-5); 10 mi. E of Maroubra (34136); 29 mi. S of Karalee (36075); 12 mi. E of Zanthus (18307). **Eucla Division** (W.A.): 25 mi. W of Caiguna (24673).

### *Morethia obscura* sp. nov.

**Holotype.**—R 16916 in Western Australian Museum, collected by Mr. John Dell on 7 November 1962 at 6 miles east of Kalamunda, Western Australia, in 31°58'S, 116°08'E.

**Diagnosis.**—Supraciliaries 6 (rarely 5), fourth largest, last three forming a decreasing series, their junction with supraoculars roughly linear. Otherwise generally similar to *M. lineocellata* and differing only in greater size, darker coloration, less distinct pattern, and invariable presence of supranasal.

**Distribution.**—Southern Western Australia: north on west coast to a little beyond the Murchison; east on south coast to Eucla; inland to Morawa, Wongan Hills, Tammin, Coolgardie and Zanthus; also many islands off lower west coast from Gun Island (Houtman Abrolhos) to Garden Island (off Fremantle). Apparently absent from far southwest, i.e. south of Bunbury and west of Albany. Extralimital in southern South Australia.

**Description.**—Snout-vent length (mm): 18-56 (43). Tail (% SVL): 126-189 (152).

Supranasal and postnasal always present, though often fused to each other or merely separated by a shallow groove. Ear lobules 1-4 (2.3). Midbody scale rows 24-30 (mostly 26 or 28, mean 27.0). Lamellae under fourth toe 17-23 (19.3), smooth or obtusely keeled.

Upper surface dark olive-grey or olive-brown. Back with or without small, usually indistinct, black-and-white ocelli or black flecks. Rarely any indication of a pale dorsolateral line. Broad black upper lateral stripe variably developed. Pale midlateral stripe usually absent or poorly developed (i.e. narrow, ragged-edged and suffused with grey).

**Material.**—**South-West Division** (W.A.): Zuitdorp Cliffs, 40 mi. N of Kalbarri (18597); Morawa (34004); Gun Island, Houtman Abrolhos (27190-2); No. 5 Island, S of Gun Island (30436); Pelsart Island, Houtman Abrolhos (27142, 27161-70, 30438-9); Fisherman Island (18386-93, 39954); Long Island, Jurien Bay (18381); Escape Island, Jurien Bay (17889); 4 mi. E of Jurien Bay (30505); Cervantes Island (18384-5); Buller Island (19154); Green Islets (18382-3); 15 mi. N of Lancelin (18396); Lancelin Island (18384-5); 7 mi. N of New Norcia (26051); Wongan Hills (4238); 8 mi. W of Bolgart (40959); Tammin (39087); Meckering (21748); Chidlow (21345); 6 mi. E of Kalamunda (16917, 19248, 19829, 22260-1, 34713, 39690); Wanneroo (14863, 34053); Crawley (18321-3); Spearwood (2768); Carnac Island (7255, 11995); Garden Island (13024, 18373-8, 35036-41); Cannington (18320); Glen-eagle (32471); Boddington (13560); Samson Brook Dam (18329); 5 mi. SW of Collie (18317); 10 mi. N of Tarin Rock (40051-3, 40096); Lake Varley (25988); 26 mi. SE of Newdegate (21736); Lake Magenta (21737); Jerramungup (18318); Toolbrunup (1385); Two People Bay (18293-4); Cheyne Beach (36040, 36016); Chillinup (26685); Bremer Bay (33402-4); Fitzgerald River Reserve (36946, 36995, 37200, 37210); Hopetoun (11010); 10 mi. N of Hopetoun (36249). **Eastern Division** (W.A.): 17 mi. S of Karalee (33991); 13 mi. W of Boorabbin (40512-4); Coolgardie (18295); 30 mi. E of Kalgoorlie (7070, 12228); 18 mi. E of Zanthus (12236). **Eucla Division** (W.A.): Mt. Holland (33990); Daniell (30785); 22 mi. N of Esperance (18292); Dalyup River (18289-90); Shark Lake (18291); Esperance (10235-6, 11369, 11782, 13397); 23 mi. E of Esperance (18288); Israelite Bay (18286, 33402-4); 4 mi. S of Mt. Ragged (17617); Junana Rock (17608-10); Pine Hill (17600-2, 22519, 36220-2); Coragina Rock

(17473, 18287, 36182); 25 mi. W of Caiguna (24674-5); 4-15 mi. SE of Cocklebiddy (24658-62, 31890-1, 34471-5, 34486, 34551-2); Madura (26436); 27 mi. S of Madura (34442-4); 22 mi. E of Madura (36660); 20 mi. S of Mundrabilla (26435); Eucla (24618-9, 31874). **South Australia**: 4 mi. E of Wilsons Bluff (28131); Ceduna (24568-9); Smoky Bay (24556-62); 17 mi. W of Port Lincoln (27365).

### **Morethia lineoocellata**

*Ablepharus lineo-ocellatus* A. M. C. Duméril & G. Bibron, 1839, "Erpétologie générale" 5: 817. New Holland.

*Morethia anomalus* J. E. Gray, 1845, "Catalogue . . . specimens . . . lizard . . . British Museum", p. 65. Western Australia (John Gilbert).

**Diagnosis.**—Supraciliaries 6 (occasionally 5, owing to fusion of first and second), third, fourth and fifth equal in size and penetrating deeply between supraoculars. Otherwise generally similar to *M. obscura* and differing only in lesser size, paler and brighter coloration, more conspicuous pattern (especially strong development of midlateral stripe and dorsal ocelli), and tendency for supranasal to fuse with nasal.

**Distribution.**—Midwest coast of Western Australia from Point Cloates south to Geraldton, and on islands from the Montebellos south to the Houtman Abrolhos; inland as far as Mt. Curious. Lower west coast of Western Australia from a little north of Perth south to Cape Leeuwin; also on islands (Rottnest and Garden) and sporadically inland as far as Canning Dam, Mooterdine and Rocky Gully.

**Description.**—Snout-vent length (mm): 19-49 (35). Tail (% SV): 111-247 (172).

Supranasal usually fused to nasal or merely separated by a shallow or incomplete groove. Postnasal usually present, though usually separated from nasal by only a faint groove. Ear lobules 1-3 (1.8). Midbody scale rows 24-31 (mostly 26 in south and 28 in north, mean 27.3). Lamellae under fourth toe 16-26 (19.7), smooth or obtusely keeled.

Head coppery brown. Back green, olive-grey or olive-brown, usually marked with black and white ocelli. Ocelli occasionally absent or modified into black and/or white spots which may coalesce into longitudinal lines. White dorsolateral line variable in development—often indistinct or absent. White midlateral stripe usually well developed and margined with black.

**Remarks.**—I have examined Gray's syntypes and have chosen one of them (British Museum 1946.8.15.75) as lectotype of *Morethia anomalus*.

**Material.**—**North-West Division** (W.A.): Trimouille Island (37464); Barrow Island (28674); Point Cloates and Ningaloo (13185, 16860-1); 11 mi. SE of Ningaloo (16977-81); 24 mi. N of Carnarvon (18328); Bernier Island (11253, 13188-91, 20516-23, 34089); Dorre Island (13186-7); Dirk Hartog Island (12474); Gladstone (18330); Car-rarang (39030). **South-West Division** (W.A.):

Gee Gie Outcamp, 21 mi. NNW of Murchison House (34037); Mt. Curious (33440); Murchison House (29923); Kalbarri National Park (37615, 37635); Lockwood Spring, 20 mi. E of Kalbarri (33476-8); 19 mi. NNW of Ajana (33665); 25 mi. W of Ajana (29625); Port Gregory (18326); East Wallabi Island, Houtman Abrolhos (18394-5); 4 mi. S of Geraldton (18327); 12 mi. W of Muchea (12702); Morley Park (32370); Rott-nest Island (2015-6, 2560, 2861-3, 2994-6, 11009, 12750-1, 12758-61, 13770, 13797, 15201-2, 17130, 18345-72, 36156); Bentley (29654, 32383); Apple-cross (21606); Spearwood (2769); Garden Island (28475-7); Point Peron (18319); Canning Dam (26483); Mooterdine (40960-1); Lake Clifton (18310-6); Wagerup (6491); Dunsborough (18308); Cowaramup (13734); Margaret River (7960-1); Karridale (27959-64); Rocky Gully (40962).

### *Morethia adelaidensis*

*Ablepharus lineo-ocellatus* var. *adelaidensis* "Peters", Boulenger, 1887, "Catalogue . . . lizards . . . British Museum (Natural History)" 3: 349. South Australia (Gerard Krefft).

**Diagnosis.**—Supraciliaries normally 5, last three largest and penetrating deeply between supraoculars; subdigital lamellae sharply keeled; ground colour slightly rufescent; pale midlateral stripe wavy-edged.

**Distribution.**—Arid southeast of Western Australia (Nullarbor Plain and vicinity), north nearly to latitude 29°S and west nearly to Kalgoorlie. Extralimital in South Australia.

**Description.**—Snout-vent length (mm): 17.5-53 (42). Tail (% SVL): 125-172 (153).

Supranasal and postnasal invariably present but often fused to each other or merely separated by a shallow groove. Ear lobules usually hidden by projecting pre-auriculars; occasionally 1-3 visible. Midbody scale rows 26-31 (mostly 28 or 30, mean 28.9). Lamellae under fourth toe 17-23 (19.8).

Dorsally olive-brown or olive-grey, variably tinged with rufous brown. Small black spots on back tending to form broken paravertebral lines. Pale dorsolateral stripe occasionally discernible on body, reappearing above eye as well-defined curving line. Broad, dark brown upper lateral stripe ill defined. Whitish midlateral stripe usually margined below with dark brown. Under digits rufous brown.

**Remarks.**—Boulenger (*supra cit.*) ascribed the name *adelaidensis* to Peters. In the cited place (Mber. Preuss. Akad. Wiss. 1874: 375-6) Peters described *Ablepharus* (*Morethia*) *taeniopleurus*, which he briefly compared with "*Ablepharus* (*Morethia*) *anomalus* (*adelaidensis*)". This passing mention of *adelaidensis* does not constitute a valid description. Nor do I believe it was Peters' intention to introduce a new name here; I think this was simply his way of referring to

Adelaide specimens of what he took to be *Ablepharus anomalus*.

I therefore regard Boulenger as the authority for the name *adelaidensis*. According to Dr Smyth (pers. comm.) the specimens of "*adelaidensis*" listed by Boulenger actually comprise two species. In order to stabilise the name, I have examined Boulenger's two South Australian specimens and have chosen one of them (British Museum 64.10.27.9) as lectotype of *Morethia adelaidensis* (Boulenger).

**Material.**—**Eastern Division** (W.A.): Randalls (18299-300); Karonie (14234-8); Naretha (18301-6, 39712-3); 100 mi. N of Loongana (29459). **Eucla Division** (W.A.): Scemore Downs (18331-8); Loongana (29430-1, 34502, 37671); Forrest (15817); 18 mi. NE of Forrest (15180); Eucla (24620-3); Mundrabilla (11001, 25470); Madura (25471); 20 mi. N and 24 mi. NE of Madura (29417-22, 36166-7); Cocklebidy (36554-5); 12 mi. SW and 14 mi. S of Balladonia (17386, 17417, 17419-20). **South Australia:** Koomoolooka Cave (25416-21); Pidinga (25422-4, 25428, 25469); Ceduna (25551); 6 mi. N of Kokatha (24506-9); Wingfield (39793-4).

### Discussion

As in some other widespread but small genera, e.g. *Nephrurus* and *Tympanocryptis*, the various species of *Morethia* tend to have mutually exclusive ranges. In the Kimberley and North-west Divisions there is only *taeniopleura*. The arid and semiarid country further south is occupied by *butleri*, which itself is replaced in the far east of the State by the closely related *boulengeri*. The ranges of the three species occurring in the south of the State, *lineoocellata*, *obscura* and *adelaidensis*, are respectively centred on the west-coastal plain, the pre-cambrian shield, and the halophytic country of the southeast. However, *obscura* has invaded the coastal plain in several places; it is also marginally sympatric with the southernmost populations of *butleri* and *adelaidensis*.

The fact that *Morethia* species are largely allopatric would suggest that they have evolved *in situ*; or in other words their ranges are much the same as when they were geographic races of a single widespread species. This might be taken as evidence that the various species are young, or have evolved too recently for their ranges to have changed much. Such a view would be supported by the great similarity in scalation between the species, only the supraciliaries showing any substantial differentiation. Moreover the relationship of *obscura* to *lineoocellata* and of *boulengeri* to *butleri* must be very close.

Nevertheless I cannot believe that the radiation of *Morethia* is very recent. The differences in coloration between, say, *taeniopleura*, *lineoocellata* and *adelaidensis* are marked and manifold, and are in no degree bridged by geographic or individual variants. Moreover the genus itself is probably old. With its persistent

supranasals and postnasals, *Morethia* stands apart from other endemic Australian genera of skinks; at the same time it is not clearly related to any non-Australian genus.

One is thus left with the probability that the restricted ranges of *Morethia* species are due to ecological factors rather than lack of time for expansion. Each species, it seems, is so well adapted to a given climate-substrate type that its congeners are at a disadvantage within its range. In *Nephrurus* and *Tympanocryptis*, where interspecific differences in morphology are more trenchant, the case for invoking ecological factors is still more cogent.

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## 9.—Prehistoric mammal faunas from two small caves in the extreme south-west of Western Australia

by M. Archer\* and A. Baynes\*\*

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### Abstract

Mammal faunas are reported from deposits in two small caves near Augusta, Western Australia. They are considered to have been accumulated by owls. Identifications by previous authors are discussed for certain species. The faunas are compared with previous records of both modern and fossil populations of each species in the area. A radiocarbon date (GaK-2949) of  $430 \pm 160$  years B. P. is reported for hair from the larger deposit, and the ages of both deposits are discussed. The youngest known fossil *Sarcophilus* specimen from the Australian mainland is reported. The first record of *Rattus tunneyi* in the extreme south-west is discussed, and it is concluded that the species extended its range into the area in the last 8,000 years. It is suggested that it reached the area via west coastal heath habitats, from the Swan coastal plain.

### Introduction

In 1968 our attention was drawn by Mr P. R. Lake to mammal bones (Western Australian Museum 67.8.5) which he had collected from small pockets in the vertical aeolian limestone face of the cliffs (Fig. 1) along the east side of Turner Brook, near Augusta in the Cape Leeuwin-Cape Naturaliste region of south-western Australia. Two of the pockets contained interesting animal remains, and results of work on these are reported in this paper. Because the pockets are too small to merit names they are referred to throughout as Cave 1 and Cave 3. They are registered as Au24 and Au25 respectively by the Western Australian Speleological Group (Mr P. J. Bridge, pers. comm.).

The vegetation in the valley adjacent to the cliffs is peppermint woodland (see Fig. 1). On

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Figure 1.—The cliffs on the east side of Turner Brook. They rise to a height of 60 m.



the higher ground this is replaced by shrubby heath. To the south the woodland gives way to heath and then mobile sand dunes near the sea shore which is about 1 km south of the caves.

The geological nature of the cliffs and these pockets is not clearly understood. The calcareous aeolianite, of which the cliff is composed, is generally assumed to be Quaternary in age and to represent consolidated calcareous dune sands which have a coastal origin (Jennings 1968). There are no absolute dates available for the particular dune in which the cliffs occur. Jennings (1968) and Bain (1962) discuss the history of the cliffs and Jennings (1968) concludes that they may have been produced as a consequence of removal by Turner Brook of the mobile dune sands that settled across its course. He suggests that vigorous stream activity resulted in a steep dune face along the east bank of the stream valley, as well as a smaller dune face along the west bank. However this interpretation is complicated by our finding, near the base of the cliffs, what appear to be rounded heads of granite cobbles that resemble coastal cobble beds present and possibly forming along the beach a few miles north of Turner Brook. Further, from the loose sediments along Turner Brook in the vicinity of the cliffs we recovered fragments of marine echinoids, bryozoans, molluscs and benthic foramina. These observations suggest that the cliffs might be sea cliffs resulting from a previous high stand of sea level. The ceilings of at least some of the small pockets in the cliff face are composed of what appears to be cemented limestone rubble, rather than simple bedded aeolianite. Similar rubble occurs in several south-west caves such as Mammoth Cave. It is therefore possible that the cliffs and their small limestone pockets may have had a different origin than that suggested by Jennings (1968).

The morphology of Cave 1 is typical of several pockets at various heights and positions along the face of the cliff. It is a wedge-shaped impression in the cliff face whose floor slopes steeply up and back into the cliff face to meet the ceiling at the rear of the pocket. There are many small horizontal solution cavities connected to the pocket. Bones occur in these small solution cavities as well as on the floor of the pocket itself. Cave 3 is a similar but much smaller pocket about 100 m upstream from Cave 1 and about 4 m vertically above the base of the cliff.

The bone-bearing deposit in Cave 1 is probably over 10 cm thick, and appears to have filled a natural depression in the floor of a horizontal solution cavity in the cave. Near the surface, the bone is abundant and there is relatively little limestone rubble. Below 8 cm the proportion of limestone rubble increases rapidly. At about 10 cm the limestone rubble comprises almost all of the deposit and at this depth there are numerous spaces into which material has fallen from higher levels. For this

reason we concerned ourselves with only the upper 8 cm of the Cave 1 deposit. The Cave 3 bone-bearing deposit had proportionately less bone and was slightly deeper. We collected a sample to a depth of 13 cm from the deposit in Cave 3.

Material was collected from the caves on three separate occasions by scooping the bone-bearing matrix into cotton specimen bags using trowels and bare hands. Bones and mammal hair were sorted from the matrix in the laboratory. After identification, estimates were obtained of the minimum number of individuals represented by counting left and right sides of skulls or dentaries etc. and treating the larger of the two figures as the minimum number of individuals. Mammal specimens were accessioned in the palaeontological collection of the Western Australian Museum (71.11.199-327). Other catalogue numbers (e.g. M8351) referred to in this paper are those of the modern mammal collections of the Western Australian Museum. Cave names are used without apostrophes in accord with the policy of the Department of Lands and Surveys of Western Australia (e.g. Devil's Lair becomes Devils Lair).

Responsibility for the identification and discussion of the mammal specimens is divided between the two authors. Marsupial and bat specimens were identified by M. Archer. Murid specimens were identified by A. Baynes. The nomenclature used here is that adopted by Ride (1970). In the case of the dasyurids, the identifications are based on revisional work within the family Dasyuridae by M. Archer, to be published elsewhere. In the case of the murids, the nomenclature used by Ride (1970) is based upon the long term research of J. A. Mahoney who has identified large numbers of murid specimens which are lodged in the Western Australian Museum collections. These series are here considered to embody the concepts implied by the names used by Ride (1970) in all cases except one. The exception is *Pseudomys praeconis*. Until recently confusion existed in identifications of specimens from cave deposits of this species and the very similar *Pseudomys nanus*. However, A. Baynes has now carried out a study on the maxillae of these species (to be published elsewhere) on the basis of which they were separated. As a result it was found that most of the specimens from caves in the Moore River-Dongara region (including a series with 63.9.1 from Hastings Cave which Mahoney had tentatively identified as *P. nanus*), and all the specimens examined from the Cape Leeuwin-Cape Naturaliste region, grouped with modern specimens of *P. praeconis*. Pending further investigation they are recorded under that name. Methods of diagnosis of rodent species used by A. Baynes will be published in the form of a key to the rodents of south-western Australia.

### Faunas

The species identified in the Cave 1 deposit within 8 cm of the surface, and the minimum

number of individuals of each species represented are listed below:

Metatheria	
Dasyuridae:	
<i>Sminthopsis murina</i>	61
<i>Antechinus flavipes</i>	57
<i>Phascogale tapoataja</i>	1
<i>Dasyurus geoffroyi</i>	2
<i>Sarcophilus harrisii</i>	1
Peramelidae:	
<i>Isodon obesulus</i>	7
Burramyidae:	
<i>Cercartetus concinnus</i>	8
Petauridae:	
<i>Pseudocheirus peregrinus</i>	1

Eutheria	
Vespertilionidae:	
<i>Nyctophilus timoriensis</i>	1
Muridae:	
<i>Pseudomys shortridgei</i>	140
<i>Pseudomys praeconis</i>	3
<i>Rattus fuscipes</i>	231
<i>Rattus tunneyi</i>	114
<i>Rattus sp.*</i>	26

\* These do not represent a third species in this genus. They are broken or incompletely developed specimens which could not be assigned to either named species with certainty.

The exact provenance of the single premolar that represents *Sarcophilus harrisii* is not certain. It was collected from the foot of the cliff immediately below a small opening that leads back into the solution cavity in Cave 1 that contained the Cave 1 deposit. Bone material in the solution cavity was found scattered as far as this opening in the cliff face. There were other small bones lying with the *S. harrisii* tooth that resembled the material from the Cave 1 deposit. This suggests that a quantity of material including the *Sarcophilus* tooth fell from the deposit.

In addition, there are numerous passerine bird specimens represented by skeletal remains. No attempt has been made to identify them. There are also insect remains which represent eleven families and four orders (pers. comm. from Mrs E. A. Archer, Western Australian Museum) and molluscan remains which represent one genus (pers. comm. from Mr G. W. Kendrick, Western Australian Museum).

The species identified in the Cave 3 deposit within 13 cm of the surface, and the minimum number of individuals of each species are listed below:

Metatheria	
Dasyuridae:	
<i>Sminthopsis murina</i>	5
<i>Antechinus flavipes</i>	24
<i>Phascogale tapoataja</i>	1
Peramelidae:	
<i>Isodon obesulus</i>	2
Burramyidae:	
<i>Cercartetus concinnus</i>	2
Phalangeridae:	
<i>Trichosurus vulpecula</i>	2
Petauridae:	
<i>Pseudocheirus peregrinus</i>	1
Macropodidae:	
<i>Potorous tridactylus**</i>	1
<i>Bettongia sp.</i>	1
<i>Setonix brachyurus</i>	1

Eutheria	
Muridae:	
<i>Pseudomys albocinereus</i>	3
<i>Pseudomys shortridgei</i>	11
<i>Pseudomys praeconis</i>	4
<i>Rattus fuscipes</i>	38
<i>Rattus tunneyi</i>	4
<i>Rattus sp.*</i>	6
<i>Hydromys chrysogaster</i>	1

\* See comment below species list for Cave 1.

\*\* The identification is based on a worn molar and may not be correct.

In addition there are mollusc specimens representing four species of terrestrial snails, one of which is an evidently undescribed prosobranch (pers. comm. from Mr G. W. Kendrick).

### Species concepts

Before proceeding with a consideration of the species contained within these deposits it is necessary to examine the concepts implied by certain names used by previous authors in discussing relevant faunas. Many of the pioneering studies on cave deposit faunas in Western Australia were carried out by E. L. Lundelius (1957, 1960, 1963, 1964 and 1966). He deposited small samples of identified specimens in the Western Australian Museum. These were catalogued several years later. Generally only one specimen in each sample received a catalogue number. Most of the specimens are from Hastings Cave. Comparisons of specimens we collected from the same deposit with those attributed to Lundelius, perhaps erroneously, reveal disagreements in identification of some of the small dasyurid and murid specimens.

Lundelius (1957) states that *Sminthopsis hirtipes* is represented in cave deposits at Jurien Bay and Mimegara. However Lundelius (1960 p. 149) later qualifies this statement as follows: "Unfortunately the identification of the species *Sminthopsis* and the genus *Notomys* is very uncertain at the present time because of the imperfect knowledge of the Recent species. There are two species of *Sminthopsis* present in Drover's Cave [Hastings Cave, see Merrilees 1968]. A small species which resembles *S. hirtipes* is abundant in the surface deposits of a number of caves north of Perth. A larger species whose affinities are unknown is abundant in the lower layer and is only doubtfully identified in the top layers." In the Western Australian Museum collections there are seven "*Sminthopsis*" samples from Hastings Cave whose collection and identification is attributed on the labels to E. L. Lundelius. Re-identifications of some of the specimens in these samples given below are based on concepts developed as a result of the revisional studies of the Dasyuridae by M. Archer. One sample (including 63.6.21 and 72.4.10) is identified by Lundelius as "*Sminthopsis sp. small*". Specimen 63.6.21 represents *S. murina* and specimen 72.4.10 represents *S. granulipes* on the criteria used here. A second sample (including 63.6.22 and 72.4.11) is identified by Lundelius as "*Sminthopsis sp. large*". Specimen 63.6.22 represents *S. granulipes* and specimen 72.4.11 represents *Antechinus flavipes* on the criteria used here. A third sample

(including 63.6.15 and 72.4.12) is identified by Lundelius as "*Sminthopsis hirtipes*". Specimen 63.6.15 represents *S. granulipes* and specimen 72.4.12 represents *S. murina* on the criteria used here. Two other samples (including 66.1.30-34 and 63.2.26) are identified by Lundelius as "*Sminthopsis murina*". All of these specimens appear to represent *S. granulipes* on the criteria used here. Two final samples (including 63.2.27, and 66.1.40-48) have associated labels indicating they were identified by Lundelius as "*Sminthopsis crassicaudata*". All of the numbered specimens in these samples are considered to represent *S. murina* except 66.1.41 and 66.1.45 which on the criteria used here are considered to represent *S. granulipes*. Cook (1960) states that his identification of *S. crassicaudata* from Devils Lair (Nannup Cave of Cook 1960, see Merrilees 1968) in the Cape Leeuwin-Cape Naturaliste region was based on comparison with specimens identified as that species by E. L. Lundelius. However, Cook did not designate the specimens he used, and Lundelius' published faunal lists from western coastal cave deposits do not include *S. crassicaudata*. Cook's specimens (65.10.150-153) are considered to represent *S. murina* on the criteria used here.

Because the specimens were accessed after Lundelius published his identifications it is impossible to be certain that the specimens in these samples were among those referred to by Lundelius (1957 and 1960). However, all of the specimens representing *Sminthopsis* species subsequently collected by us from Hastings Cave are considered to represent only *S. murina* and *S. granulipes*. Further, as a result of examination of modern and fossil dasyurids, it is possible to say that these are the only species of *Sminthopsis* (as presently understood) known to have inhabited the coastal plain south of the Jurien area. These re-interpretations are important because inferences of past climates from fossil faunas by Lundelius (1960) are in part drawn from the presumed presence of the arid adapted *S. hirtipes* in the Hastings Cave deposit.

Lundelius (1957, 1960) recognizes four species of the murid genus *Pseudomys* in cave deposit faunas from the west coast of Australia: *P. shortridgei*, *P. occidentalis*, *P. albocinereus*, and *P. nanus*. The samples of specimens lodged in the Western Australian Museum, labelled identified by Lundelius as *P. shortridgei* (including 63.6.11) and *P. occidentalis* (including 63.6.12) are in accord with the concepts of these species used here. In the case of *P. albocinereus* the sample consists of three specimens (63.6.16, 72.4.13 and 72.4.14), which were collected, and apparently identified by Lundelius. Only 63.6.16 is judged to be *P. albocinereus*, 72.4.13 and 72.4.14 are considered to be juvenile *P. occidentalis* on the criteria used here. This may result from misassociation of label and specimens, as Lundelius (pers. comm.) is confident he correctly separated these species. The samples (including 63.6.20 and 70.6.28) labelled identified by Lundelius as *P. nanus* are among those indicated by the study referred to above to be probably *P. praeconis*.

Lundelius (1960) lists two species of *Rattus* in faunas from west coast cave deposits. *R. fuscipes* he considered to be present in all those he reported on, i.e. between Cape Leeuwin and Jurien Bay. In addition he recognized a second species from the more northern deposits in this region which he identified only as *Rattus* sp. He deposited in the Western Australian Museum a single sample of *Rattus* maxillae (including 63.6.19) from Hastings Cave, which the label indicates he identified as *R. fuscipes*. All six specimens in this sample are considered to be *Rattus tunneyi* on the criteria used here. Research being carried out by A. Baynes on the fauna from Hastings Cave deposit shows that *R. fuscipes* is indeed present, but the specimens are considerably smaller than both *R. tunneyi* specimens from the same deposit, and *R. fuscipes* specimens from the Cape Leeuwin-Cape Naturaliste region. As will be shown below, it is probable that the *Rattus* sample from Devils Lair examined by Lundelius (1960) included only *R. fuscipes*. Although Lundelius (1960) makes no comment on the relative sizes of the species he separates, it is possible that he identified specimens in the northern deposits as *R. fuscipes* on the basis of larger size, and placed the small (true *R. fuscipes*) specimens under *Rattus* sp. Thus in Lundelius' records from the Cape Leeuwin-Cape Naturalist region *R. fuscipes* is probably correctly identified, whereas for deposits north of Perth *Rattus* species appear to be confused.

#### Previous records in the region

It is useful to consider whether the species have been collected live and what their known

Table 1

The distribution of species which occur in the Cave 1 and Cave 3 faunas

	Re- corded live from the region	Cave 1	Cave 3	Devils Lair	Pleisto- cene deposit in Mam- moth Cave
<i>Sminthopsis murina</i>	+	+	+	+	+
<i>Antechinus flavipes</i>	+	+	+	+	+
<i>Phascogale tapoatafa</i>	+	+	+	+	+
<i>Dasygale geoffroyi</i>	+	+	+	+	+
<i>Sarcophilus harrisii</i>	+	+	+	+	+
<i>Isodon obesulus</i>	+	+	+	+	+
<i>Cerculestes caninus</i>	+	+	+	+	+
<i>Trichasurus calperula</i>	+	+	+	+	+
<i>Pseudochelone peregrina</i>	+	+	+	+	+
<i>Potorous tridactylus</i>	+	+	+	+	+
<i>Bettongia penicillata</i>	+	+	+	+	+
<i>Petaurus lesurii</i>	+	+	+	+	+
<i>Selolus brachyurus</i>	+	+	+	+	+
<i>Nactophilus timorensis</i>	+	+	+	+	+
<i>Pseudomys albocinereus</i>	+	+	+	+	+
<i>Pseudomys shortridgei</i>	+	+	+	+	+
<i>Pseudomys praeconis</i>	+	+	+	+	+
<i>Rattus fuscipes</i>	+	+	+	+	+
<i>Rattus tunneyi</i>	+	+	+	+	+
<i>Hydromys chrysogaster</i>	+	+	+	+	+

+ = present.  
- = absent.

fossil record is in the Cape Leeuwin-Cape Naturaliste region. This information is summarized in Table 1.

There are only two relevant dated bone-bearing deposits in this region: the Pleistocene deposit in Mammoth Cave (reviewed most recently by Merrilees 1968) and the deposit in Devils Lair (reviewed most recently by Dortch and Merrilees 1972). The ages of these deposits are discussed below. Other fossil faunas from this region reported by Glauert (1948), Cook (1963) and Merrilees (1968 and 1969) have not been radiometrically dated.

*Sminthopsis murina* was reported by Shortridge (1910) to occur live near Margaret River in the Cape Leeuwin-Cape Naturaliste region. Dortch and Merrilees (1972) recorded the species as a fossil from Devils Lair. Specimens (e.g. 68.6.286) known from the Mammoth Cave deposit are considered to represent this species.

*Antechinus flavipes* (e.g. M 2037) is known live from the Cape Leeuwin-Cape Naturaliste region. Cook (1963) considered a single fossil tooth from Strongs Cave possibly to represent *Antechinus flavipes*. Dortch and Merrilees (1972) report fossil *A. flavipes* from Devils Lair. Lundelius (1960) reports fossil specimens of *Antechinus* ? from Devils Lair. Specimens (e.g. 68.6.285) considered to represent *A. flavipes* are known from the Mammoth Cave deposit.

*Sarcophilus harrisii* has only been recorded live on the Australian mainland in Victoria, but there is some doubt about the interpretation of these records (discussed below). The species is known as a fossil from the Cape Leeuwin-Cape Naturaliste region, for example from Mammoth Cave (Merrilees 1968), Devils Lair (Lundelius 1960, Dortch and Merrilees 1972), Strongs Cave (Cook 1963), Brides Cave (Glauert 1948), and Labyrinth Cave (Merrilees 1969).

*Phascogale tapoatafa*, *Dasyurus geoffroii*, *Isodon obesulus*, *Trichosurus vulpecula*, *Pseudochairus peregrinus*, and *Sctonix brachyurus* have all been collected live from the Cape Leeuwin-Cape Naturaliste region (Shortridge 1910), and all are represented by fossils from Devils Lair (Lundelius 1960, Dortch and Merrilees 1972) and Mammoth Cave (Lundelius 1960 or Merrilees 1968).

*Cercartetus concinnus* is represented by specimens (e.g. 10510) in the modern mammal collections of the Western Australian Museum from the Cape Leeuwin-Cape Naturaliste region. It was also evidently known to Aborigines who inhabited the area within historic times (Shortridge 1910). It has been reported as a fossil by Cook (1963) in the Strongs Cave fauna, and by Dortch and Merrilees (1972) from Devils Lair.

*Potorus tridactylus* may now be extinct in the Cape Leeuwin-Cape Naturaliste region (Shortridge 1910). It has been reported as a fossil for example from Strongs Cave (Cook 1963),

Mammoth Cave (Merrilees 1968) and Devils Lair (Lundelius 1960, Dortch and Merrilees 1972).

Because of the nature of the material (one molar) representing *Bettongia* sp. it has not been possible to determine which of the two living species known from south-western Australia is represented in the Cave 3 material. *Bettongia penicillata* has been collected live from the Cape Leeuwin-Cape Naturaliste region (Shortridge 1910). Although it occurs in the Devils Lair deposit (Dortch and Merrilees 1972), it has not been reported from the Strongs Cave deposit and is probably not represented in the Pleistocene deposit in Mammoth Cave (see Merrilees 1968). *Bettongia lesueur* has neither been collected live from this region nor been recorded from the Mammoth Cave deposit (Merrilees 1968). It is, however, recorded from Devils Lair (Lundelius 1960, Dortch and Merrilees, 1972).

*Nyctophilus timoriensis* has not been recorded live from the Cape Leeuwin-Cape Naturaliste region. The closest record (M976) is from the Pemberton area. Cook (1963) records the species as a fossil from the Strongs Cave fauna.

*Pseudomys albocinereus* is not known as a modern population from the Cape Leeuwin-Cape Naturaliste region. The closest records are from near Fremantle (Shortridge 1936), and the Chorkerup-Narrikup area north of Albany (e.g. M1732, M3417). However, it is represented in the Devils Lair deposit (Lundelius 1960, Dortch and Merrilees 1972).

*Pseudomys shortridgei* has not been collected live from the Cape Leeuwin-Cape Naturaliste region and is poorly known as a modern population in Western Australia. On the other hand it is generally abundant in prehistoric faunas from the west coast (e.g. Lundelius 1957), and the south coast at least as far east as Bremer Bay (Butler and Merrilees 1971). It is also known from the Devils Lair deposit (Lundelius 1960, Dortch and Merrilees 1972).

*Pseudomys praeconis* is another species not known as a living animal from the Cape Leeuwin-Cape Naturaliste region, and indeed it has been regarded as confined to the Shark Bay region (see, for instance, Ride 1970). Lundelius (1957) reported *P. nanus* from Lake Cave. As shown above, this record probably represents *P. praeconis*. A single specimen is also listed by Dortch and Merrilees (1972) from Devils Lair. The importance of the records lies in the recognition of this species in the extreme south-west, indicating a much wider former distribution. A substantial reduction in range of true *P. nanus* is also implied, casting doubt on the extension of range suggested by Lundelius (1957).

*Rattus fuscipes* is still very common in coastal habitats of south-western Australia, and is well represented by specimens in the Western Australian Museum. Four (M8351-8354) were

trapped by M. Archer and others along Turner Brook near Cave 1. This species is also generally well represented by specimens from the surface of many cave deposits in the Cape Leeuwin-Cape Naturaliste region. Lundelius (1960) recorded *R. fuscipes* as the only species of *Rattus* in the Devils Lair deposit, and it was the only representative of the genus obtained from the same deposit by Dortch and Merrilees (1972). Lundelius (1960) also lists this species from the Mammoth Cave deposit, but the specimen(s) on which he based this record are not designated. There are two *Rattus* specimens (65.4.39-40) from the Mammoth Cave deposit in the Western Australian Museum; both are considered to represent *R. fuscipes* on the criteria used here.

*Rattus tunneyi* (Fig. 2) is not known as a living animal from the Cape Leeuwin-Cape Naturaliste region, the closest record being that listed by Mahoney (1969) from "Perth—lakes".

It was originally described from northern Australia and for many years was only known from that part of the continent. The species is apparently absent from the Devils Lair deposit, but is known from the surface of deposits in four other caves in the Cape Leeuwin-Cape Naturaliste region: 70.6.87 from a cave near Mammoth Cave, 70.7.199 from Skull Cave, 71.6.26 from Yallingup Cave, and 72.2.1 from the Brides Cave doline.

*Hydromys chrysogaster* is distributed in river systems of south-western Australia. Although live specimens were not reported from the Cape Leeuwin-Cape Naturaliste region by Shortridge (1936), the Western Australian Museum collections include modern specimens (M6576, M6580, M6581) from the stream system which flows through Mammoth Cave, and fossil specimens (e.g. 68.4.188) from a small number of caves in the same region.

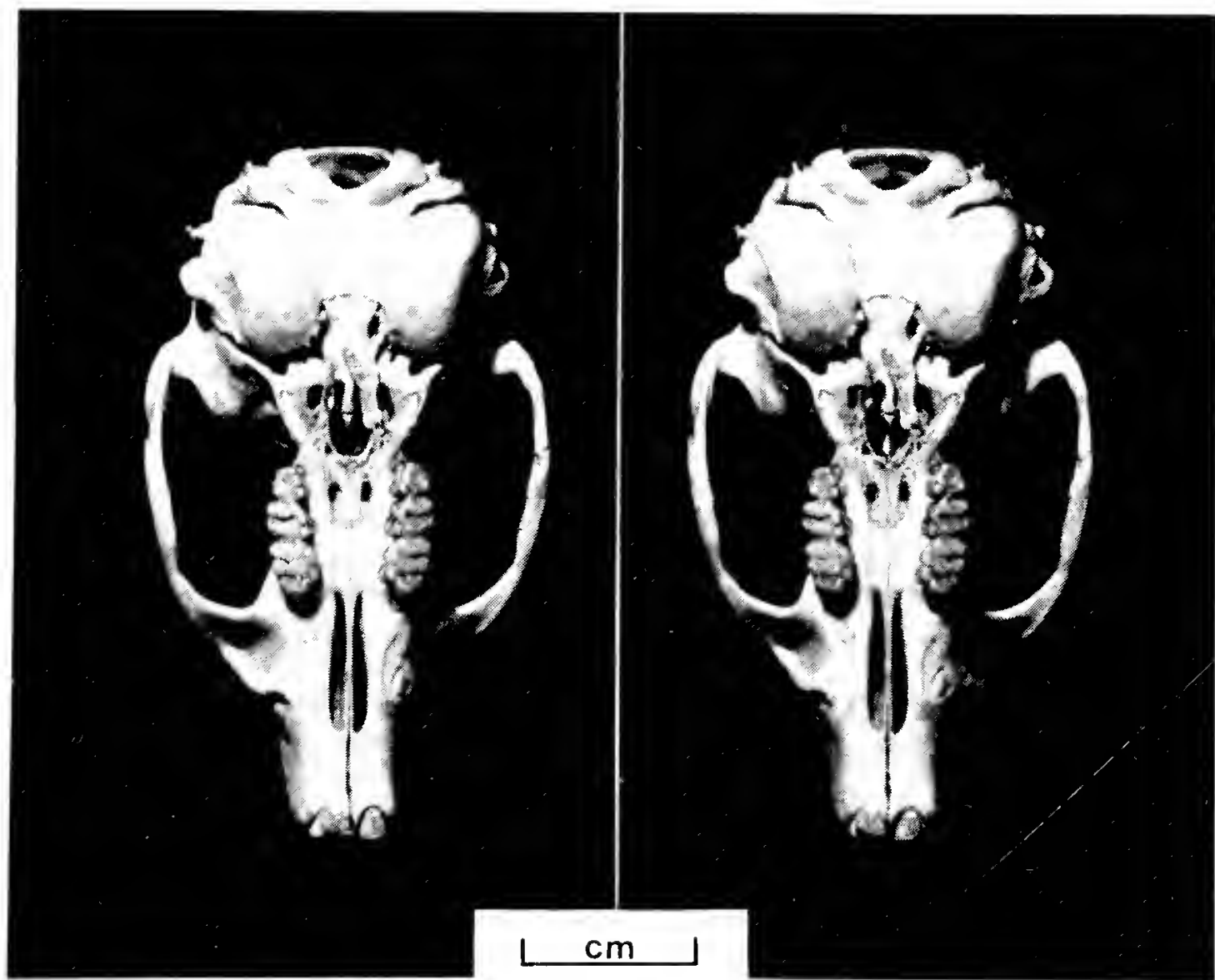


Figure 2.—Stereo-pair of ventral view of skull of *Rattus tunneyi* (71.11.224) from Cave 1. The very large bullae characteristic of this species are easily seen. This very well preserved specimen is one of many from the deposit.



### Age of Deposits

Lundelius (1960) reports two radiocarbon dates for Devils Lair (= Nannup Cave of Lundelius, see Merrilees 1968):  $8500 \pm 160$  years B.P. for material collected from immediately under the travertine floor which covered the excavation site and  $12175 \pm 275$  years B.P. for a sample collected from a depth of four feet. Dortch and Merrilees (1972) describe further studies in Devils Lair and report on faunal remains between and below the dated levels of Lundelius (1960). Lundelius (1960) also reports a radiocarbon date of greater than 37000 years B.P. for a sample of charcoal taken from the excavation site in Mammoth Cave. Merrilees (1968) reports a date greater than 31500 years B.P. for a smaller amount of charcoal collected from the same excavation site.

Hair (49 gms) from the mammals represented throughout the 8 cm interval excavated from the Cave 1 deposit was submitted for radiocarbon dating. The result of the assay (GaK-2949) was a date of  $430 \pm 160$  years B.P. No material suitable for radiocarbon dating was recovered from the Cave 3 deposit.

The only other evidence available, on the relative ages of the Cave 1 and Cave 3 deposits, and for defining the periods over which they accumulated, is from the contained faunas. In neither are there remains of any introduced mammal species. *Mus musculus*, *Rattus rattus*, and *Oryctolagus cuniculus* are all represented by specimens (e.g. 68.4.12, 72.3.21, 65.12.295 respectively) from other cave deposits in the Cape Leeuwin-Cape Naturaliste region. Further, M. and E. Archer trapped *Rattus rattus* (M8355) along Turner Brook near Cave 1. It therefore

seems likely that accumulation in both caves ceased before any of these species reached the Turner Brook area. Shortridge (1936) states that *Mus musculus* and *Rattus rattus* were collected at Margaret River between 1904 and 1907. Rabbits probably arrived later. Shortridge (in Thomas 1907) notes that they had not reached the south-west of Australia when he was collecting in the area.

The Cave 3 fauna includes *Pseudomys albocinereus*, but it is absent from Cave 1 (discussed below). This species was recovered from each interval of the excavation made in Devils Lair by Dortch and Merrilees (1972). It therefore appears to have been established in the area for a long period of time. This suggests that accumulation may have begun earlier in Cave 3 than in Cave 1, and that *P. albocinereus* may have become locally extinct between these two events.

### Discussion

#### Agents of Accumulation

The preponderance of small mammals in both faunas, and the relatively undamaged state of the skulls of many of the specimens (see Fig. 2) suggests that owls were the predators responsible for the accumulation of mammal remains in Cave 1 and Cave 3. Further support for this interpretation is provided by the occurrence in the Cave 1 deposit of skull and dentaries of single individuals in small discrete masses which may represent partially decomposed owl pellets (e.g. *Antechinus flavipes* 71.11.273). Teeth of *Sarcophilus harrisii* were found in another south-western cave deposit (Kangeroo Pot) in-

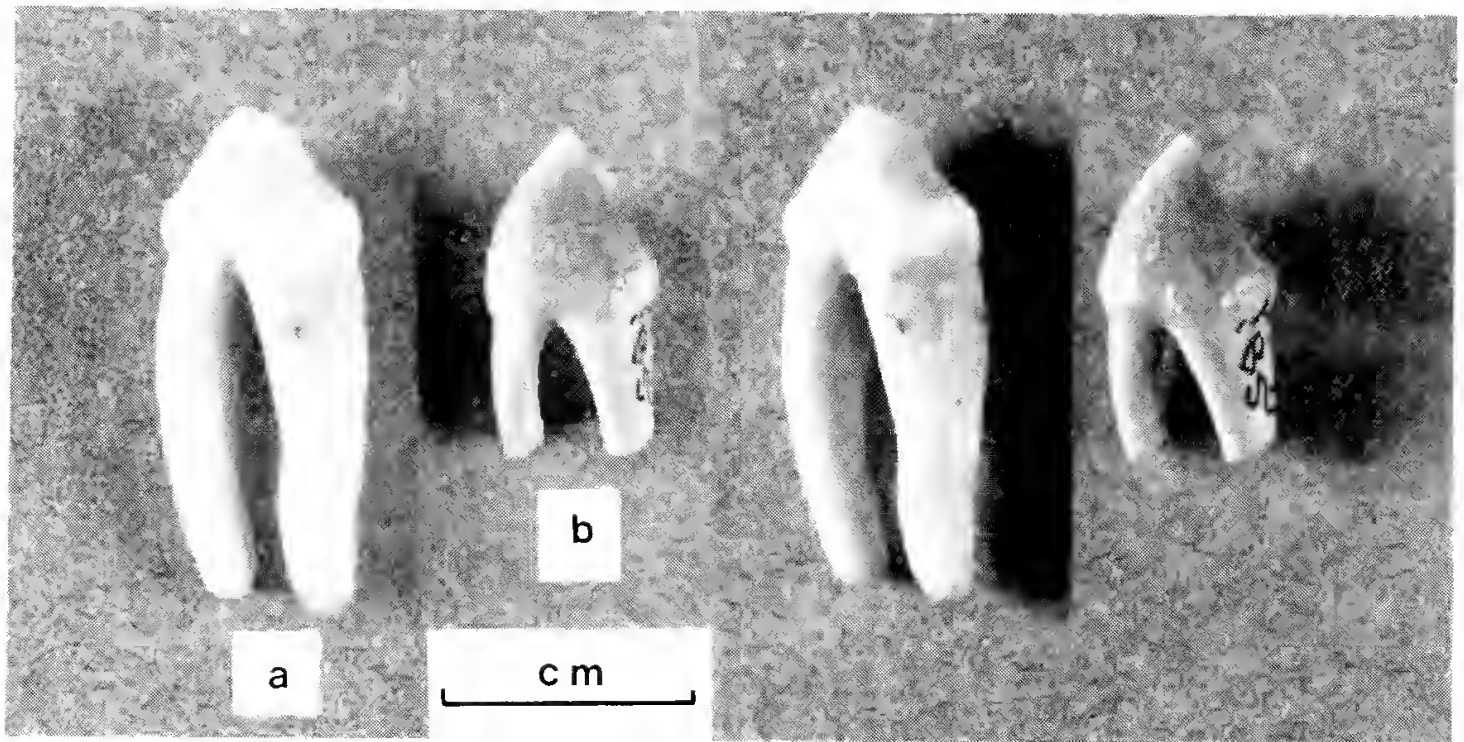


Figure 3.—(a) Stereo-pair of an upper third right premolar of an adult specimen (M6556) of *Sarcophilus harrisii*. (b) Stereo-pair of the upper third right premolar (71.11.285) of *Sarcophilus harrisii* from Cave 1. The much shorter open-ended roots of the Cave 1 specimen indicate that it represents a juvenile individual.

vestigated by one of us (Archer, yet to be published), which is also interpreted as an owl pellet deposit. In both cases the *Sarcophilus* teeth are unworn and have poorly formed roots (Fig. 3). They were almost certainly unerupted and would represent pouch-young individuals within the size range of prey normally taken by large owls. Although it is possible that a mammalian carnivore contributed part of the Cave 1 or Cave 3 deposits including the juvenile individual of *Sarcophilus harrisii*, there are no broken or chewed bones, coprolites, or other evidence normally considered to suggest the activities of a mammalian carnivore (see Lundelius 1966) in either deposit. In addition the relatively inaccessible situation of Cave 3 would make any but bird predators unlikely there.

The total number of individuals recorded in the fauna from Cave 3 (107) is only about one sixth that of Cave 1 (653), yet the number of species from Cave 3 (16) is slightly higher than from Cave 1 (13). This greater diversity is principally due to the inclusion in the Cave 3 deposit of single specimens of larger mammal species typical of south-western faunas. It seems probable that the differences in the faunas reflect the presence of different or additional owl predators in Cave 3. Not only the widespread medium-sized owl species, *Tyto alba* and *Ninox novaeseelandiae*, but also the much larger *T. novaehollandiae* and *N. connivens* are found in the extreme south-west of Australia (Serventy and Whittell 1967). Either of the last two could be powerful enough to prey upon all the mammal species included in the fauna from Cave 3.

Since the greater diversity of prey species is found in the smaller deposit, Cave 3, it is reasonable to assume that the owl predators which accumulated the fauna in the larger deposit, Cave 1, adequately sampled the small mammal species occurring in the area. It follows that the absence of *Pseudomys albocinereus* from Cave 1 reflects a genuine absence from the contemporary fauna.

#### *Species records of significance*

*Sarcophilus harrisii* has been recorded live from the Australian mainland only twice, in 1912 at Tooborac sixty miles from Melbourne, and in 1971 near Ballarat (noted in *The West Australian* for 25 May, 1971). Ride (1970) suggests that, although it is commonly thought that the Tooborac animal had escaped from captivity, there is no certainty that this was the case. The same comment could also apply to the specimen captured near Ballarat. *Sarcophilus harrisii* has been reported from fossil bone deposits in Victoria (e.g. Gill 1955), South Australia (e.g. Wakefield 1964), Northern Territory (Calaby and White 1967) and Western Australia (e.g. Merrilees 1968). Gill (1955) reports a radiocarbon date of  $538 \pm 200$  years B.P. for *Sarcophilus harrisii* from the Tower Hill Beach locality of western Victoria. However,

Gill (1971) more recently considers that this association is erroneous and that "... the *Sarcophilus* is about 5,000 years old at this site". Lundelius (1960) reports that the species is represented on the Swan coastal plain of Western Australia in the Wedges Cave deposit from a level which is dated at  $3750 \pm 240$  years B.P. Calaby and White (1967) consider the Northern Territory record of *Sarcophilus harrisii* to be not older than 3,120 years. This was previously the youngest record from the Australian mainland.

The specimens of *Sarcophilus harrisii* (noted above) from the Kangaroo Pot deposit which has been dated at  $620 \pm 90$  years B.P. (GaK-3477) add weight to the evidence from Cave 1 that the species survived until late Recent time in south-western Australia. In view of the date of  $430 \pm 160$  years B.P. (GaK-2949) reported here for Cave 1, *Sarcophilus harrisii* might even have been living in the south-west of Australia at the time of European settlement.

Three of the taxa represented in the Cave 1 and Cave 3 faunas are not recorded in the Devils Lair fauna by Dortch and Merrilees (1972). *Nyctophilus timoriensis*, like most bat species, is poorly represented in Western Australian cave deposit faunas, so the significance of the record cannot be assessed. *Hydromys chrysogaster* is another species not often found in cave deposits. The lack of a record from older deposits might indicate a recent arrival in the area, but it seems much more probable that it has simply not been sampled by predators contributing to cave deposit faunas. On the other hand, the absence of *Rattus tunneyi* from older faunas is considered meaningful. It is possible that the species was present in the Cape Leeuwin-Cape Naturaliste region at the time of accumulation of the Devils Lair deposit, but because of its restriction to a coastal heath habitat some distance from the cave, was not sampled by the owl predators. However the fauna obtained from the deposit by Dortch and Merrilees (1972) includes other species which are characteristic of drier heath habitats. The absence of *R. tunneyi* from the deposit therefore probably indicates genuine absence from the area at the time of accumulation of the Devils Lair deposit. Its presence in Cave 1 and Cave 3, and only on the surface in other caves in the Cape Leeuwin-Cape Naturaliste region, would suggest a late invasion (or perhaps re-invasion) of the area. To place this hypothesis on a really sound footing evidence of appearance in a dated stratified deposit is necessary. Data of this type are also needed before an attempt can be made to correlate time of arrival with past climatic changes interpreted from independent evidence, such as that used by Churchill (1968).

Serventy and Whittell (1967) postulate that the Eyrean bird species found in the coastal regions of the extreme south-west of Australia reached these localities via western and southern corridors of heath communities. These exist between the coasts and the forest block which they consider forms a barrier to movement of

such birds. The habitats occupied by *Rattus tunneyi* range from open woodland to coastal sand dunes (Ride 1970), but are not known to include sclerophyll forest. It therefore seems likely that this rat reached the Cape Leeuwin-Cape Naturaliste region via one (or both) of these coastal heath corridors.

*Rattus tunneyi* is abundant as a member of cave faunas from Yanchep to Dongara, and is present through the full depth of the deposit in Hastings Cave, which spans from at least 11,000 years ago to the present (A. Baynes unpublished observations). It thus appears to have been established throughout a long period of time as a member of the fauna of the Swan coastal plain. There are abundant remains (e.g. 71.1.413) of this species among material from a surface site at the mouth of the Donnelly River (at approximately lat. 34° 29' S, long. 115° 41' E), and there is a single specimen (71.2.24) from a cave at Windy Harbour (at approximately lat. 34° 50' S, long. 116° 0' E). However, there is no evidence that the species has occurred further east than this on the south coast either in historic or prehistoric times. It was not obtained by the early collectors working north from King George's Sound (but was collected at about the same time on the Victoria Plains—see Mahoney 1969). It was also not in a prehistoric fauna collected by Butler and Merrilees (1971) at Bremer Bay, which was radiocarbon dated using bone at 1190 ± 80 years B.P. It is therefore more probable that the species reached the Cape Leeuwin area from the Swan coastal plain population via the western corridor. From there it may have continued on to the south coast.

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# 10.—Information on Western Australian earthquakes 1849-1960

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## Abstract

To complement previously published data on the seismicity of Western Australia, earthquake data for the period 1849-1900 are summarised, and those for the period 1900-1960 reassessed.

The first known earthquake report in Western Australia was during 1849 when Perth was noticeably shaken.

The Geraldton, Barrow Range, and Roebourne regions have a history of seismic activity prior to 1900 although little activity has occurred in these areas since then. Of particular interest is an 1885 earthquake located off-shore near Geraldton which generated a minor tsunami thereby suggesting a magnitude of 6.5 or more.

Epicentres and magnitudes (ML) are estimated for sixteen earthquakes during the period 1900-1960. All but one of these were in the South-west Seismic Zone, to the east of Perth, where activity appears to have increased markedly since about 1940.

A body wave magnitude of 7.1 is determined for the 1941 Meeberrie earthquake. This determination tends to confirm macroseismic evidence that this event is the largest known earthquake to have occurred in Australia to date, and that the depth of focus is greater than normal for continental earthquakes.

## Introduction

A description of the seismicity of Western Australia (Everingham, 1968a) revealed an inadequate knowledge of earthquakes which occurred in the period prior to October 1959 when the Mundaring Geophysical Observatory commenced seismological recordings with modern instruments. Prior to this the details of only one earthquake in Western Australia (at Meeberrie in 1941) were known, whereas subsequently over two hundred were located for the relatively short period October 1959-June 1965. No details of seismicity prior to 1900 were given in Everingham's report.

In order to improve knowledge of earlier events further investigations were carried out, with the result that additional information was found to be available from three main sources. These were (a) newspaper and Meteorological Bureau reports of events which happened prior to 1900; (b) seismograms of the Milne Shaw seismograph operating at the Perth Observatory (station PER) during the period 1923-1960; and (c) intensity data contained in the Perth Observatory files covering the period 1923-1960.

## Data for the period prior to 1900

The earliest known reference to Western Australian seismicity is a legend to be found in a book of aboriginal legends named "An Attempt to Eat the Moon", by Deborah Muller-Murphy (1958). The legends pertain to the area in the vicinity of Busselton and the one of interest here, entitled "The Great Shaking", gives a vivid description of earthquake (and perhaps volcanic and weather) effects which were accompanied by changes in the topography and sea level. The existence of the legend suggests that a major earthquake which occurred unknown centuries ago was destructive enough to make a lasting impression on the local population.

The only list of data on earthquakes that occurred before 1900 appears to be that published by the Commonwealth Bureau of Meteorology (1929). Their volume gives very brief descriptions of earthquake reports during 1849-1927, those for the 1900-1927 events being much the same as descriptions extracted from Perth Observatory files by Everingham (1968a). The first known map of earthquake reports in Western Australia also appear here. Although the first earthquake listed took place in 1849, the Bureau pointed out that the information was accumulated regularly only after 1878 so that further reports of 1829-1878 tremors may be discovered in the future.

Newspapers were searched for references to events listed by the Bureau of Meteorology, and extracts from these references are listed in the Appendix. Where a newspaper report of a listed earthquake could not be discovered, the details given by the Bureau of Meteorology were used.

Descriptions of three events not listed by the Bureau of Meteorology are also given in the Appendix; of particular interest is the description contained in a log of Ernest Giles' inland exploration journey of 1873.

For this study no attempt was made to search for earthquake reports in every newspaper published before 1900. To locate reports in this manner would be extremely time-consuming and probably inefficient because of the difficulty in reading the archival microfilm copies of the newspapers and because of the haphazard way in which reports were included in these newspapers. Even when the dates of events were known, the authors often found it difficult to locate the reports in the newspapers.

The earthquake which caused the highest felt intensities (probably Modified Mercalli (MM)

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6 or 7) prior to 1900 were at Barrow Range (1873) and Geraldton (1885). A one metre drop in sea level reported to have been associated with the Geraldton event is a typical tsunami effect caused by submarine land-sliding or faulting and indicates an off-shore epicentre for the earthquake. A shallow earthquake with a magnitude (MS) of at least 6.5 would probably be required to cause such a sea-wave (Iida, 1963).

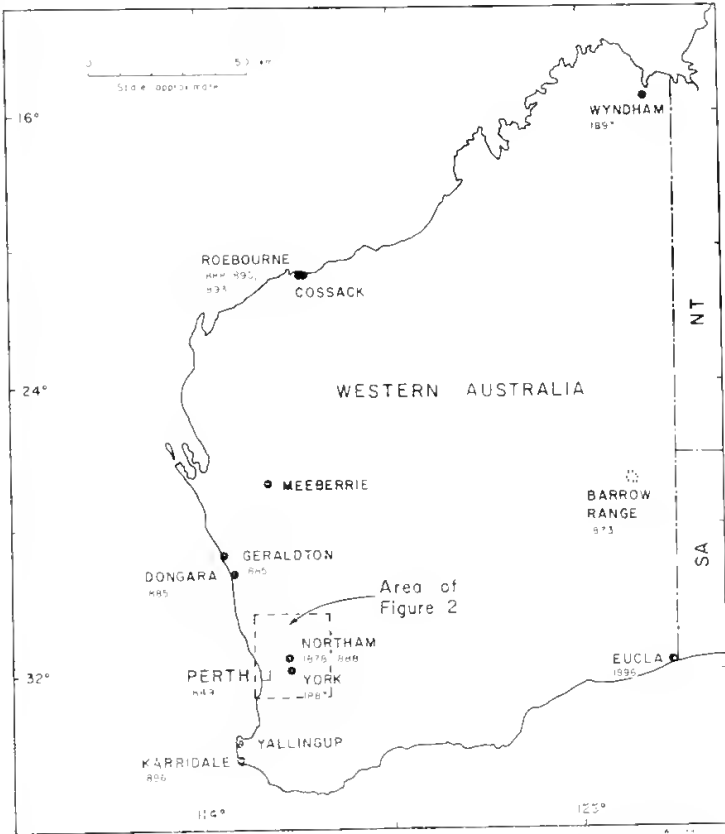


Figure 1.—Locality map. The year of pre-1900 earthquakes is shown beneath the town or locality affected.

Assuming a magnitude of 7.0 or less, the felt intensities suggest an epicentre within about 100 km distance from Geraldton.

With the exception of the Table Mountain event of 1885 (position unknown) localities of these earthquake reports listed in the Appendix are plotted on Figure 1.

Data for the period 1900-1922

All but a few years of the Perth Observatory seismograms for the period 1904-1922 when the Milne seismograph was in operation, could not be located. However this type of recording, extremely crude by modern standards, would have been of little use for the study of the relatively small magnitude earthquakes which occurred during that period. Also, the population was sparse, newspaper descriptions and filed reports from the public pertaining to tremors were sketchy and consequently it was not possible to improve the data tabulated by Everingham (1968a) in his Table 5.

In view of the occurrences of the major earthquake with surface faulting near Meckering on 14th October, 1968, it is interesting to find that the first known reports of earth tremors in the vicinity of the fault plane were in 1911 and 1916 and that otherwise, prior to the fortnight before the major event, no further significant activity was noted there.

Data for the period 1923-1960

Intensity data used for the location of epicentres

Because of the experience gained in recent years, it was possible to determine epicentres of most of the Western Australian earthquakes recorded on the improved Milne-Shaw seismograph by scrutinizing the Perth Observatory

Table 1  
South Western Australian earthquakes recorded at  
Perth Observatory 1923-1960.

Year	Date	Approx. Origin Time G.M.T.	Place	Lat S	Long E	Magnitude	
						ML*	ML
1940	Dec 18	2145	Beverley-Brookton	32.2	117.2		4.2
1946	Apr 19	2113	West of Yallingup	(33.5)	(114.5)		5.7
1946	Sep 17	1512	Pingelly	(32.5)	(116.9)		4.5
1949	May 02	1000	Yericoin	30.9	116.4		5.1
1949	May 07	1709	Yericoin	30.9	116.4		4.1
1952	Mar 11	0609	Bolgart	31.3	116.5	(4.6)	5.1
1954	Nov 27	0836	Talbot Brook	(32.0)	(116.7)		3.9
1955	Apr 29	0914	Yericoin	30.9	116.4	(5.1)	4.7
1955	Apr 29	1949	Yericoin	30.9	116.4		4.4
1955	Aug 29	0509	Gabalong	30.7	116.4		5.3
1955	Aug 30	1352	Gabalong	30.7	116.4	(5.5)	5.8
1955	Aug 30	1.07	Gabalong	30.7	116.4		4.7
1955	Aug 30	1656	Gabalong	30.7	116.4		4.6
1956	Feb 24	0627	Yericoin	(30.9)	(116.4)		4.5
1956	Apr 05	2313	Yericoin	(30.9)	(116.4)		4.5
1958	Mar 20	0303	Beverley-Brookton	32.3	117.2	(5.2)	4.8

NOTES : ML relative determinations from max. trace amplitude NS Milne-Shaw recording at PER.  
ML\* magnitude estimated from intensity data.  
32.2 accuracy  $\pm 0.25$ .  
(33.5) accuracy  $\pm 0.5$ .



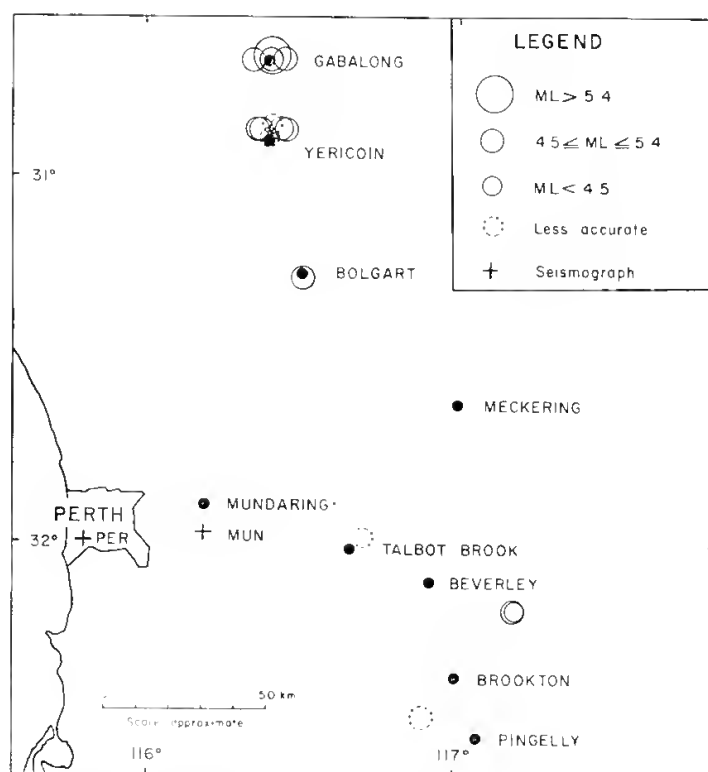


Figure 2.—Earthquakes in the active zone to the east of Perth recorded by the Perth Observatory Milne-Shaw seismograph, 1923-1960.

files of earthquake reports and newspaper cuttings. For example, Carrigy and Main, of the University of Western Australia, sent out a number of intensity questionnaires for earthquakes which occurred at Bolgart (1952), Yericoin (1955) and Gabalong (1955) (see Figure 2), and replies to these clearly indicated the epicentral regions; in other examples the similarity of reports with those from areas which have been active since 1960 gave a good lead to the epicentral position. Moreover, it was possible to use the S-P time on the Milne-Shaw seismograms converted to epicentral distance (using recently determined travel-times), to roughly confirm the distance from Perth to the epicentres determined from the felt reports.

Fortunately many epicentres could be determined fairly accurately because: (a) most of the events recorded at Perth were large enough to be felt clearly; (b) the focal depths of local events are generally very shallow so that maximum intensities are felt in very localised areas close to the epicentres; and (c) reports of frequent loud explosive sounds caused by aftershocks and foreshocks are commonly made from areas within a few kilometres of the main shock.

In some instances the Perth Observatory wrongly reported that a local felt earthquake was recorded on the seismogram, e.g. a distant event recorded at the time a local tremor was felt at Albany on 2 February, 1937, was assumed to have caused the shaking of that town. In other instances recordings were weak or undecipherable and did not provide any additional information.

The epicentres are listed in Table 1. Except for the 1946 event to the west of Yallingup all events were in the South-west Seismic Zone (the known NNW-SSE trending zone of activity, about 60 km east of Perth described by Everingham, 1968a) and the positions of these epicentres are shown in Figure 2.

### Magnitude determinations

Magnitudes were estimated in two ways: (a) approximately from intensity information discussed above; and (b) from the Milne-Shaw seismograms, assuming a nominal magnification of 250.

Where there was sufficient information, the felt intensities for a given earthquake were compared with those experienced in recent earthquakes of known magnitudes, and for which isoseismal maps have been drawn (see Everingham and Parkes, 1971). Four magnitudes estimated in this manner are included in Table 1 under the heading ML\*.

Because the periods of ground motions could not be measured on the Milne-Shaw recordings, the trace amplitudes could not be converted to standard Wood-Anderson amplitudes for determination of local magnitude values. However, using the maximum trace amplitudes registered on the Perth Milne-Shaw seismogram and the nomogram of Gutenberg and Richter (1942), relative local magnitudes (ML) of eighteen events were determined. The level of these magnitudes was then adjusted so that the mean value of the four determinations from isoseismals equalled the mean value of the relevant four determinations using the Milne-Shaw records. Results are listed in Table 1. Magnitude values are probably accurate to 0.5 units.

Table 2

*Meeberrie (1941) earthquake Determinations.*

Magnitude determined from	Magnitude (MS)	Assumed focal depth (km)	Remarks and reference
surface waves	6.8	shallow	Gutenberg and Richter (1954). Depth factor not included in magnitude formula.
isoseismals	(6.9*)	30	Bolt's (1959) depth. *Magnitude determined by Everingham and Parkes (1971).
isoseismals	(7.7*)	60	Gutenberg and Richter's (1954) depth. Also approximate depth indicated by macroseismic data (Everingham and Parkes, 1971).
body waves	7.3	shallow	Depth not critical. Body wave magnitude (mB) = mB(MUN) + 0.1 where mB (MUN) is determined using Everingham's (1968b) curve B for attenuation function. Converted to MS via mB = 2.5 + 0.63 MS.

It is suggested by Everingham and Parkes (1971) that the 1941 Meeberrie earthquake surface wave magnitude ( $M_S = 6.8$ ) given by Gutenberg and Richter (1954) is too low because the earthquake focal depth was probably in the vicinity of the maximum depth (50 km) for which the method of surface wave magnitude determination is applicable. To throw further light on this suggestion, a body wave magnitude was determined from the Perth Observatory seismogram using the currently standard empirical method employed by the Mundaring Geophysical Observatory (Everingham, 1968b). Table 2 lists the result along with other magnitude determinations for the earthquake.

The body wave magnitude, admittedly not very accurate because of its derivation from the Milne-Shaw recording, does tend to confirm that the magnitude determined from surface waves is too low. It is considered that in view of the evidence given in Table 2 a magnitude ( $M_S$ ) of 7.2 and Gutenberg and Richter's (1954) focal depth of 60 km should be adopted for the Meeberrie earthquake.

The 1941 Meeberrie event is apparently the deepest and largest known to have occurred in the Australian continent since instrumental recordings commenced in the early 1900's. The 1968 earthquake at Meckering with  $M_S$  6.8 is the second largest to have occurred in Australia.

It is unfortunate that for the one event (3 October 1959) which was recorded at both Mundaring and Perth Observatories before the Milne-Shaw seismograph at Perth was closed down, the recording from Perth was spoilt by traffic noise and a direct comparison of magnitudes determined from each instrument could not be made.

### Conclusions

Pre-1900 newspaper reports of pronounced earthquakes at Geraldton (1885), Barrow Range (1873), and Roebourne (1888-1893) are interesting because there has been practically no evidence of activity in these regions since 1900. The areas should be considered as 'active' areas in earthquake risk analysis.

The 1849 report of shaking in Perth is the earliest known report of a tremor, and in Perth the intensity ( $MM5?$ ) experienced then was probably not exceeded until 1968, when the Meckering earthquake caused intensities of up to  $MM6$ .

As a result of careful inspection of seismic records, newspaper cuttings and Perth Observatory files for the period 1900-1960, epicentres and magnitudes of 16 minor earthquakes in the South-west Seismic Zone were determined with reasonable accuracy; also a body-wave magnitude was obtained for the 1941 Meeberrie

earthquake. This earthquake, with magnitude  $M$  7.2, is the largest one to have occurred in Australia since about 1900.

Within the South-west Seismic Zone, most of the centres listed in Table 1 which were seismically active during the period 1923-1960 have also been active since then (Everingham, 1968a). Tremors in the area have been noted relatively frequently since 1878, but they have become more frequent since 1940. The Perth seismograms prove that earthquakes with magnitudes ( $M_L$ ) of 4.5 or greater could not have occurred in the zone during the period 1923-1939, and the observed effects suggest that none occurred during 1900-1922. However, during the period from 1940 to the end of 1967, 12 earthquakes with  $M_L$  4.5 or more had occurred in the area and during 1968-1970 there were a further six.

### Acknowledgements

The authors' attentions were drawn to the reports of the 1873 earthquake in Giles' diary by Dr. J. Daniel and to the Bureau of Meteorology (1939) publication by Mr. D. Walker. Their assistance and the services of the archival section of the Library Board of Western Australia are gratefully acknowledged. This work is published with the approval of the Director of the Bureau of Mineral Resources.

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## Appendix: Earthquake Felt Reports, 1849-1900

1849 August 4, Perth

*Inquirer*, 8 August 1849:

'On Saturday last, about a quarter past four o'clock a.m., several of the inhabitants of Perth were awakened by what they conceived to be a slight shock of an earthquake; it was momentary, but quite sufficient to make the glasses ring, and to shake the articles of furniture in the rooms, such as the bedsteads etc. The same phenomenon was observed at Fremantle and Guildford. This is the first time such an occurrence has been noticed in Western Australia, which bears no trace of having been recently a volcanic country, and is not therefore liable to those disturbances of the earth's surface felt in existing volcanic regions. If this were a slight shock, it will most probably be found to be nearly simultaneous with one of greater severity that has happened elsewhere, some great distance away, of which it was a prolongation and perhaps the terminative effect. We cannot hear that any damage was effected, or indeed that any trace of its visit has been left to substantiate the fact of a shock having occurred. The weather at the time was perfectly calm, although there were several heavy showers during the night, and some thunder and lightning'.

*Perth Gazette*, 10 August 1849:

'Early on the morning of Saturday last, shortly after four o'clock several persons in Perth, Fremantle and Guildford were aroused from their slumbers by what is supposed to have been a slight shock of an earthquake, but whatever nature the mysterious visitant was of, a motion of the earth was very perceptible, and sufficiently strong to shake the houses and the articles of furniture in them, particularly the bedsteads, which appear to have been special articles of visitation, causing some of the occupants to quit them in haste; report says that one gentleman looked under his bed to see if the earthquake was there, and that another peeped out of his window to see which way it was going'.

1873 December 15, Barrow Range

*Giles's Diary*, Vol. 1. Ch. V. pp. 240-242:

'I was in a state of bewilderment at the thought of the water having so quickly disappeared, and I was wondering where I should have to retreat to next, as it appeared that in a day or two there would literally be no water at all. I felt ill again from my morning's walk, and lay down in the 110° of shade, afforded by the bough gunyah which Gibson had formerly made.

I had scarcely settled myself on my rug when a most pronounced shock of earthquake occurred, the volcanic wave, which caused a sound like thunder, passing along from west to east right under us, shook the ground and the gunyah so violently as to make me jump as though nothing was the matter with me. As the wave passed on, we heard up in the glen to the east

of us, great concussions, and the sounds of smashing and falling rocks hurled from their native eminences rumbling and crashing into the glen below. The atmosphere was very still today, and the sky clear except to the deceitful west.

Gibson is still so ill that we did not move the camp. I was in a great state of anxiety about the water supply, and Tietkens and I walked first after the horses, and then took them up to the glen, where I was enchanted to behold the stream again in full flow, and the sheets of surface water as large and as fine as when we first saw them. I was puzzled at this singular circumstance, and concluded that the earthquake had shaken the foundations of hills, and thus forced the water up; but from whatsoever cause it proceeded, I was exceedingly glad to see it. Today was much cooler than yesterday. At three P.M., the same time of day, we had another shock of earthquake similar to that of yesterday, only that the volcanic wave passed along a little northerly of the camp, and the sounds of breaking and falling rocks came over the hills to the north-east of us.

Gibson was better on the 17th, and we moved the camp up into the glen where the surface water existed. We pitched our encampment upon a small piece of rising ground, where there was a fine little pool of water in the creek bed, partly formed of rocks, over which the purling streamlet fell, forming a most agreeable little basin for a bath'.

1873 December 23, Barrow Range

*Giles's Diary*, Vol. 1. Ch. VI, p. 247:

'... rocks above us so that he and Jimmy had need to defend themselves with firearms. Our bough-house was a great protection to them, and it appeared also that these wretches had hunted all the horses away from their feeding ground, and they had not been seen for three days, and not having come up to the water all the time we were away. At four P.M., we had our afternoon earthquake, and Gibson said the shock had occurred twice during our absence'.

1878 March 17, Northam

'A slight earthquake shock was felt here and for a few miles north of the town at 4 p.m.'

1885 January 5, Geraldton

*Morning Herald*, 7 January 1885:

'I have to report that a slight shock of earthquake occurred here last night, somewhere about 10 o'clock. The ground was sensibly shaken and all the windows and doors of our houses by their rattling, slamming and shaking indicated that an earthquake was occurring. The sensation produced resembled very much that which is occasioned by the rattling of the wheels of a vehicle or the still more rumbling noise of a succession of railway carriages in motion'.

*Victoria Express, 7 January 1885:*

'About five and twenty minutes past ten on Monday evening the inhabitants of Geraldton were startled—many from their slumbers—by a severe shock of earthquake. The shock appeared to travel from a north-easterly direction and was preceded by a peculiar subterranean murmur lasting some seconds. This was followed by a tremor of the earth, which shook buildings and their contents in a most alarming manner. The shock from its first premonitory murmur to its complete subsidence must have lasted fully twenty seconds; and was of exceptional severity. Walls rocked, casements and the contents of rooms rattled loudly, and a gentleman informs us that his bird was thrown off its perch. It aroused almost everybody in the town and for a time caused considerable consternation. There was no electrical disturbances in the air, the night being clear, calm and chilly for the time of year. Shortly after the shock the sea subsided fully three feet in a quarter of an hour, but there was no subsequent rush of the tide, the water rising gradually. According to the cable news we publish in another column the earth appears to have been in a state of great disturbance during the past few days in Europe, and we anticipate receiving further intelligence of a very heavy earthquake in some parts of the world not very remote from ourselves.

Further particulars are to hand concerning the shock, and we learn from one of the men in charge at Point Moore Lighthouse that the shock was so severely felt there that he was almost thrown off his feet. Mr. du Boulay informs us that the shock was also felt with much severity at his residence at Woorrie. A correspondent at Northampton telegraphs to us that the houses in the town were violently shaken and that a number of people were greatly frightened but no damage was done.

The shock does not appear to have been felt at the Gascoyne as our Carnarvon correspondent reports nothing unusual has occurred here, and the weather is fine and considering the season moderately cool. Up to the time of going to press we had received no information from Perth as to whether the shock was felt there'.

*West Australian, 7 January 1885:*

'A severe shock of earthquake occurred here about half past ten o'clock last night, preceded by a strange subterranean rumbling, and lasting about ten seconds. Houses were violently shaken by the tremor and walls rocked, causing much consternation. The sea, also, subsided about three feet in the course of a quarter of an hour, and then gradually returned to its ordinary level. The weather at the time was clear and the temperature cold'.

*West Australian, 12 January 1885*

'From Geraldton a correspondent writes:—"At about 10.45 p.m. on the 5th instant, we were all greatly astonished by an earthquake shock which lasted for fully 30 seconds. So

great was the alarm excited that one lady fainted, others shrieked, and many persons rushed into the streets in great consternation. I, with others, was in Hosken's Hotel at the time; the building was shaken from top to bottom, and I must confess I was really startled, while the amazement depicted upon the countenances of my companions was a sight to see. We hastened to the outer door whether persons rushed from all parts of the house to inquire the cause of the extraordinary vibration of the building. The shock seemed to come from a north easterly direction and some people declare that it was preceded by a rumbling noise. There is no doubt the shock has been generally felt in this district, and we may expect to hear of volcanic disturbances of some magnitude elsewhere'.

*1885 March 17, Table Mountain  
(Upper Gascoyne)*

A slight but distinct earthquake shock occurred at 7.40 p.m. A rumbling sound like distant thunder was audible for nearly 10 seconds.

*1885 May 8, Geraldton, Dongara, Greenough  
West Australian, 11 May 1885:*

'A very heavy shock of earthquake took place at six o'clock this morning and lasted fully three quarters of a minute, in the direction of East to West. Persons were thrown from one side of their bed to the other, houses rocked violently and the disturbance altogether was of an extraordinary and alarming kind. The weather was very overcast and threatening. It is reported from Greenough that the shock was very heavy there, displacing plaster at the police station. Giles of the eastern valley reports that his house rocked tremendously and was nearly thrown down'.

*Morning Herald, 11 May, 1885:*

'If we are destined to chronicle more of earthquakes in our colony similar in character and duration to the one just reported to have occurred at Dongara, our colony will be gaining for itself the reputation that New Zealand has for earthquakes. The last earthquake reported as having taken place at Dongara, on the 8th instant, is said to have been the most severe and alarming of any that have yet taken place in or about that locality'.

*Victoria Express, 16 May, 1885:*

'Mr. L. C. Burgess of Oakabella writes, "On Friday morning about 6 a shock of earthquake occurred travelling apparently from the S.S.E. I at first thought it was the cook coming in with my coffee the door being shaken as if by someone's hand. I was dressing at the time, and the sundries on my dressing table and wash stand rattled violently. Several persons on my station felt the shock".'

'Mr. Logue also writes in informing us that the shock of earthquake was felt with alarming distinctness and from all quarters we hear of its severity.

1887 April 24, York

A slight shock was experienced at York at 9.20 p.m. Residents stated that the buildings shook perceptibly. In Perth many people noticed a rumbling and trembling about the same time. The shock was also felt to the east.

1888 September, Cossack

An earthquake shock occurred.

1888 September 27, Northam

*West Australia*, 28 September 1888

Northam, 27 September. 'A slight but distinct shock of an earthquake was felt here on Tuesday about 2 p.m. accompanied by a loud report. Windows were distinctly heard to rattle and the vibration was apparent to many outlying farmers who confirm the report'.

1890 December 7, Cossack, Roebourne

*West Australian*, 9 December 1890:

'The shock of an earthquake was felt about half past two yesterday afternoon over Roebourne and Cossack. News has been received that it was also felt thirty miles to the eastward, and twenty miles to the westward. Most likely it was felt all over the district. The shaking lasted for half a minute, and was followed by a rumbling sound lasting for a minute. The sound increased to a loud roar, then died away again. It resembled the approach of a passing train. It woke several people who were sleeping at the time.

(The Colonial Secretary has received the following telegram from the weather observatory at Cossack. "Cossack, Dec. 8, shock as if caused by an earthquake felt here about 2.30 p.m. yesterday. Doors and windows of dwellings considerably shaken. Shock felt for about 50 seconds. Direction of report, N.W. to S.E.")'.

1893 April 27, Roebourne

*North West Times*, 29 April 1893:

'An earthquake shock of about twenty seconds duration occurred on Thursday morning a few minutes after 6 o'clock.'

*West Australian*, 29 April, 1893:

'A shock of earthquake was experienced here yesterday morning at a few minutes after six o'clock, lasting about twenty seconds.'

1896 April 20, Karridale

*West Australian*, 21 April 1896:

'The Inspector of telegraphs (Mr. W. E. Snook) last evening received the following message from the postmaster at Karridale:—"At 8.15 this evening a loud explosion was accompanied by earth tremors. The building shook very perceptibly.'

*West Australian*, 22 April 1896:

'A severe earth tremor, accompanied by violent explosions, was felt here about eight o'clock last night, and caused much alarm among the inhabitants. The shock seemed to travel from south to north and lasted for about fifty seconds.

(The gist of this telegram appeared in our "News and Notes" column yesterday morning.—Ed.)'

1896 June 3, Eucla

A slight earthquake shock was felt about 8 p.m. and lasted 60 seconds; the telegraph station was severely shaken.

1897 October 14, Wyndham

*West Australian*, 15 October 1897:

'A telegram was received at the Perth Observatory yesterday from the resident Magistrate at Wyndham stating that at about 2 o'clock that morning a shock of earthquake took place in that town. The vibrations of the earth travelled East to West and lasted about ten seconds. No rumbling was noticed.'



# 11.—*Hakea rubriflora* (Proteaceae), a new species from Western Australia

by Byron Lamont\*

Manuscript received and accepted 21 March 1972

## Abstract

A new species of *Hakea*, *H. rubriflora*, is described. This species has affinities with *H. pritzelii* and *H. prostrata* but the inflorescence and floral morphology of *H. rubriflora* are quite distinct. *H. rubriflora* is widespread in the Stirling-Eyre District of Western Australia.

## Introduction

Plants of a previously undescribed species were included in a study by the author of the root systems of *Hakea* species in south western Australia. This species was first collected by Gardner and Blackall in 1928, but these specimens, as well as those collected subsequently, were regarded as a form of *H. prostrata* R.Br. All material collected by the author, together with that already held at the Western Australian Herbarium (PERTH) and the University of Western Australia (UWA), conforms to the description given here. The description is based on specimens from the type population on the northern sandplain bounding the Stirling Range.

## *Hakea rubriflora* Lamont, sp. nov.

Section *Hakea*: Series *Glabriflorae* (after Benth., 1870).

Frutex 2-3 m altus. Ramuli divaricati, flexuosi, irregulati obtusanguli, flavidi vel rubri. Cortex lacvis. Ramuli et folia juvenes trichomatibus brevibus appressis. Folia elliptica (3:1) vel obovata (6:5), apice rotundata vel acuta, basi decurrentia cuneata vel cordata, 2-5 cm longa, 1-3 cm lata; margines dentatae, rarius denticulatae vel integrae, sclerenchymatae. Florae ternae aggregatae in axillaribus annotinis, duae ad folium accedentes, tertia ad caulem, foetidae. Squamae ad infimum pedunculi pusillae et paucae, caducae. Torus rectus. Pedunculi 1 mm, glabri. Pedicelli 4-7 mm, glabri. Tubus perianthii sub limbo revolutus, ad flexum 0.9-1.4 mm. Segmenta perianthii ad maturitatem secedentes et e pedicello 20-30° sursum flexi, abaxialiter vitellini, adaxialiter rutilantes, margines atosanguineae. Limbi segmentum superiorum reflexi, inferiorum lateriflexi, in senectute torti, parum concavi, cremei tandem atosanguinei. Nectarium truncatum, latissime 1.2 mm, depressicne rubrotincta. Loculi antherorum linearis paralleli, connectivo procurrente. Pistillum e pedicello 30-40° deorsum flexum. Stipes obturbatus, sulco perspicuo longitudinale per ovarium et stylum currente, 1.6 mm latus. Stylus crociaeformis, filiformis, perianthium breviter excedens, 1.1-1.7 cm latus,

versus ovarium ruber rosae. Praebitor pollinis obconus rectus; discus parum convexus. Fructus ovatus (2.4-3.1), apice late acuta, margine adaxiale quam abaxiale rotundiore, 2-3 cm longa, 0.8-1.2 cm lata, 0.8 cm crassitudo, pagina rugosa; appendices non nisi suturarum margine vel carentes, 0.5-1.5 cm longa. Semen asymmetricum acutum, basi rotundatum, 1.7-2.2 cm longum; nucleus 6-8 mm; ala in margine supera leviter decurrens, 1.1-1.4 cm longa.

Divaricate shrub, 2-3 m tall. Branchlets flexuose, irregularly obtuse-angled, yellow to red. Bark smooth. Trichomes short appressed on young stems and leaves. Leaves elliptic (3:1) to obovate (6:5), apex rotund to acute, base decurrent, cuneate to cordate, margins dentate, rarely denticulate or entire, sclerenchymatous, length 2.5 cm, breadth 1-3 cm. Inflorescence an axillary cluster of three flowers, two towards the leaf, the other towards stem; borne on previous season's branchlets. Flowers with foetid odour. Scales at base of peduncle small and few, caducous. Torus straight. Peduncle 1 mm, glabrous. Pedicels 4-7 mm, glabrous. Perianth tube revolute under the limb, 0.9-1.4 cm to summit. Perianth segments linear, separating as they mature to recline upwards 20-30° from axis of pedicel, abaxial surface dull yellow, adaxial surface orange-red, margins red-black. Limb of upper segments reflexed, and of lower segments recurved, twisting during senescence, slightly concave, cream becoming red-black. Nectary truncate, 1.2 mm at widest diameter, concavity tinged red. Pollen sacs linear and parallel, with connective slightly exceeding anther. Pistil reclined downwards 30-40° from axis of pedicel. Stipe obturbinate, with distinct longitudinal groove which may continue through ovary and style, 1.6 mm long. Style crozier-like, filiform, slightly exceeding perianth, length 1.1-1.7 cm, increasingly rose-red towards ovary. Pollen presenter obconical, straight; disc slightly convex. Fruit ovate (2.4-3.1), apex broadly acute, adaxial margin more rounded than abaxial, length 2-3 cm, breadth 0.8-1.2 cm, width 0.8 cm, surface wrinkled, appendages, if present, restricted to edge of sutures, length 0.5-2 mm; apex of seed asymmetrically acute, base rounded, length 1.7-2.2 cm; nucleus 6-8 mm; wing slightly decurrent along upper margin, length 1.1-1.4 cm.

## Herbarium Material

*Holotype*: 28 miles east of Cranbrook, north Stirling Range. 21 Oct. 1971, Lamont 1034 (UWA).

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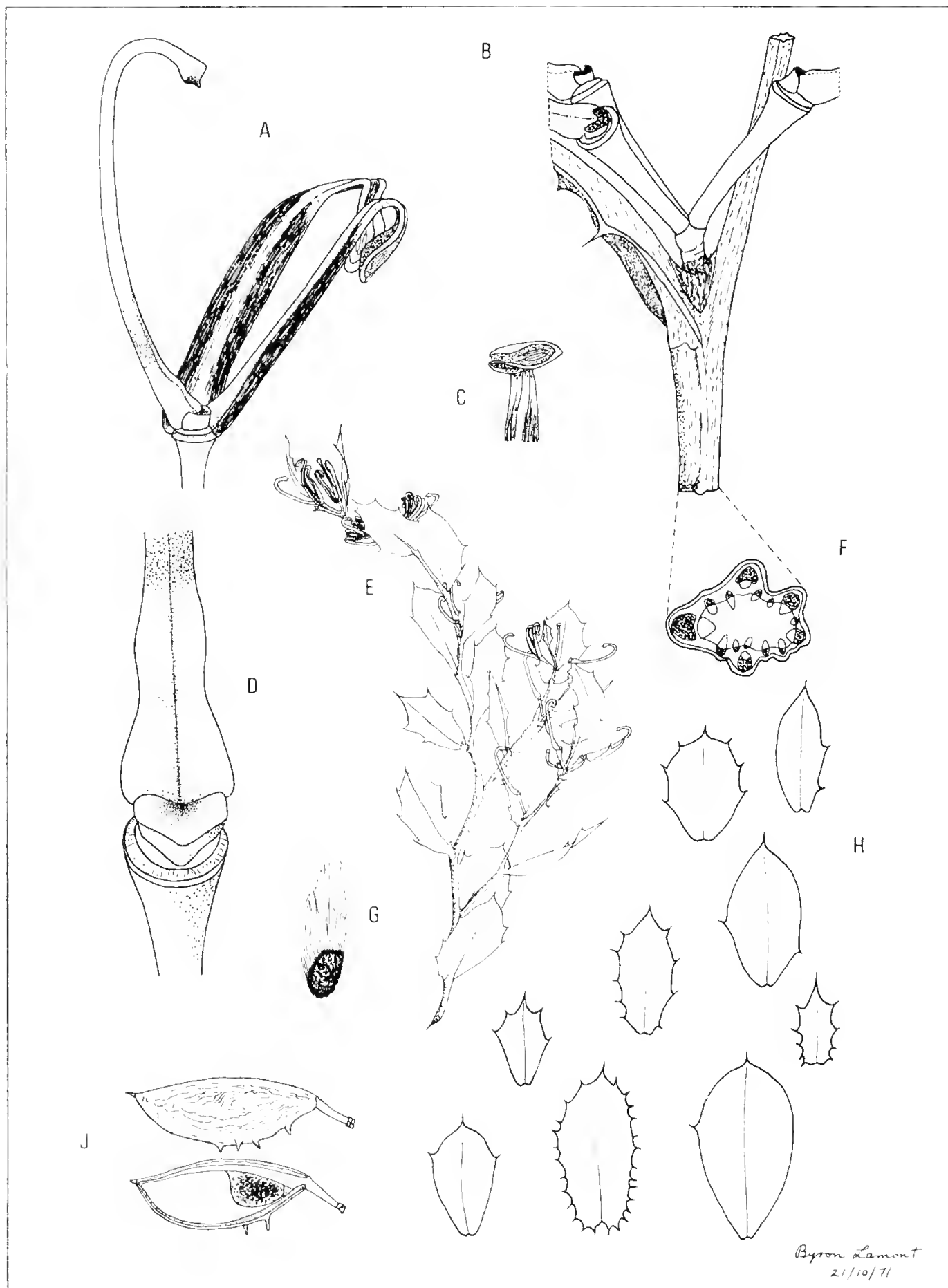


Figure 1.—*Hakea rubriflora* Lamont, sp. nov. A, — half-flower, x 4.5; B, — inflorescence in relation to axis, x 4.5; C, — limb of old perianth segment, x 4.5; D, — ovary, stipe, nectary, torus, adaxial view, x 14; E, — flowering branch, x 0.5; F, — stem, transverse section, x 14; G, — seed, x 0.9; H, sample of leaf shapes, x 0.6; J, — follicle, x 0.9

*Isotypes*: These have been deposited at the following herbaria: K (2 sheets), PERTH (2 sheets), UWA (2 sheets), AD (2 sheets), MEL (2 sheets).

*Other specimens*: NE Kalgan R., S Stirling Rd, Aug., George 188; near Porongorup Range, Steenbohm; Chillinup, E Stirling Range, Oct., 1928, Gardner 2161; Chillinup, E Stirling Range, Oct., 1928, Gardner and Blackall; Cheyne Bay turnoff, Hassell Hwy, Oct., Lamont and Newby; (PERTH). 43 ml peg, Chester Pass, Stirling Range, Oct., Lamont; 5 ml S Chillinup Pool, Pallinup R., Oct., Lamont and Newbey; 1 ml NW Boat Harbour, Cheyne Bay, Oct., Lamont and Newby; (PERTH and UWA). N Kalgan R., Albany-Borden Rd, Aug., Brittan; S Stirling Rd, Aug., Baird; junction S Stirling Rd and Albany-Borden Rd, Aug., botany students; Bremer Bay, Speck; Arboretum, Ongerup, Oct., Lamont and Newbey; (UWA).

### Discussion

As their fruits are similar, *Hakea rubriflora* is most likely to be confused with *H. pritzelii* and red-flowered forms of *H. prostrata* (see Fig. 1). However, the orange-red perianth segments with red-black margins of *H. rubriflora*, from which its name is derived, are quite distinct. In addition, the species has a three-flowered inflorescence, not 8 to 20 per cluster as in *H. pritzelii* and *H. prostrata*; the pollen presenter is straight, not oblique; the stipe is obturbinate, not cylindrical; the leaves are decurrent, not auriculate and the base of the seed in *H. rubriflora* is unevenly rounded, not acute as in *H. pritzelii* and *H. prostrata*. At the young seedling stage *H. rubriflora* may be determined by the large number of marginal teeth (10-20 per cm) with 1 mm and 0.5 mm long teeth generally alternating, the obtuse-angled stem and appressed trichomes. Young seedlings of *H.*

*pritzelii* and *H. prostrata* have less than 10 uniform teeth per cm of leaf margin, the stem is evenly rounded and the trichomes are erect.

*Hakea rubriflora* is endemic to the South-West Botanical Province (after Diels and Pritzel 1905). The species covers a triangular area, the northern boundary extending from north-west of the Stirling Range to at least Esperance (250 miles), and the south-east boundary corresponding with the coastline east of Two Peoples Bay. *H. rubriflora* is restricted to the sandplains where it occurs on soils which range from dry, deep fine sands to seasonally-waterlogged clay-gravel. It is usually codominant with other proteaceous scrub species (after Specht 1970) of similar size. Individual plants flower for little more than two to three weeks during the period August to October. Because of the shrub's foetid odour when in flower it is known locally as the stinking *Hakea*.

### Acknowledgements

Thanks are extended to Dr. N. M. Pritchard, visiting lecturer in the Botany Department, University of Western Australia, from the University of Aberdeen, Scotland, and to Mr. A. S. George of the Western Australian Herbarium for their assistance with the manuscript. This work was carried out during tenure of a Commonwealth Post-graduate Research Award in the Botany Department, University of Western Australia.

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# 12.—The Mygalomorph spider genus *Stanwellia* Rainbow & Pulleine (Dipluridae) and its relationship to *Aname* Koch and certain other diplurine genera

by Barbara York Main\*

Manuscript received 19 October 1971; accepted 20 June, 1972

## Abstract

The genus *Stanwellia* Rainbow and Pulleine is redefined and distinguished from other Australian diplurine spiders. Four already named species are attributed in the genus, two new species described and several unnamed populations are discussed. Significance of the biology and distribution of the genus and its New Zealand affinities are mentioned. The genus *Aname* Koch is discussed and the systematic position of species hitherto included in this genus reassessed.

## Introduction

The genus *Stanwellia*, although common and widely distributed in South Eastern Australia, has received little mention in the literature records of Australian Mygalomorphae. This is due in part to its confusion with the poorly defined genus *Aname* Koch. *Aname* has provided the dumping ground for numerous diplurine species, many of which properly belong in other genera (see Table 1).

The uncertainty of generic placement of many Australian diplurines is because of the sexual dimorphism of adults, a feature common to all Mygalomorphae. The palp and modifications of

the anterior legs of mature male Mygalomorphs have customarily been used in diagnoses of genera and species. However the bulk of Mygalomorphs in museum collections consist of haphazardly or randomly collected specimens. Thus many earlier systematists have had little evidence on which to associate males and females. This has often resulted in species being attributed to the wrong genus and occasionally an incorrect specific association of a male and female. The author has been able to determine the correct relationship of males and females of many species and thereafter to establish generic distinctions, by the following methods. Immature males have been collected from burrows found in aggregates of specimens of which the identity of the females is known. These immature males, recognizable as such by the slightly swollen palpal tarsi, have then been reared to maturity in flower pots of soil. Secondly, pit-traps into which wandering males fall, have been set down in sites where females of known species have been observed. Thirdly, wandering males have sometimes been fortuitously collected 'on location'. Search has then revealed conspecific females in their burrows.

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Table 1

Species originally attributed to *Aname* Koch and their revised generic positions

Species	Revised generic position
<i>Aname arborea</i> Hogg 1901	= <i>Stanwellia grisea</i> (Hogg 1901)
<i>Aname bicolor</i> Rainbow 1914	= <i>Atrax bicolor</i> (Rainbow 1914) (*)
<i>Aname armigera</i> Rainb. & Pull. 1918	= <i>Dekana armigera</i> (Rainb. & Pull. 1918) or (?) <i>Aname armigera</i>
<i>Aname aurea</i> Rainb. & Pull. 1918	= <i>Dekana</i> sp. prob. <i>grandis</i> ?
<i>Aname butleri</i> Rainb. & Pull. 1918	= <i>Stanwellia grisea</i> (Hogg 1901)
<i>Aname coenosa</i> Rainb. & Pull. 1918	= <i>Aname coenosa</i> Rainb. & Pull. 1918 or <i>Dekana</i> sp.
<i>Aname comosa</i> Rainb. & Pull. 1918	= <i>Dekana diversicolor</i> Hogg 1901 (?)
<i>Aname confusa</i> Rainb. & Pull. 1918	= <i>Stanwellia nebulosa</i> Rainb. & Pull. 1918
<i>Aname decora</i> Rainb. & Pull. 1918	= <i>Stanwellia hoggi</i> (Rainbow 1914)
<i>Aname flavomaculata</i> Rainb. & Pull. 1918	= <i>Ixamatus flavomaculatus</i> (Rainb. & Pull. 1918)
<i>Aname fuscocincta</i> Rainb. & Pull. 1918	= <i>Ixamatus fuscocinctus</i> (Rainb. & Pull. 1918)
<i>Aname grandis</i> Rainb. & Pull. 1918	= <i>Dekana grandis</i> (Rainb. & Pull. 1918)
<i>Aname grisea</i> Hogg 1901	= <i>Stanwellia grisea</i> (Hogg 1901)
<i>Aname hirsuta</i> Rainb. & Pull. 1918	= <i>Dekana diversicolor</i> Hogg 1901 (?)
<i>Aname intricata</i> Rainb. & Pull. 1918	= <i>Chenistonia intricata</i> (Rainb. & Pull. 1918)
<i>Aname maculata</i> Rainb. & Pull. 1918	= <i>Chenistonia tepperi</i> Hogg 1901
<i>Aname minor</i> Kulcz 1908	= ? <i>Ixamatus</i>
<i>Aname nebulosa</i> Rainb. & Pull. 1918	= <i>Stanwellia nebulosa</i> (Rainb. & Pull. 1918)
<i>Aname pallida</i> Koch 1873	= <i>Aname pallida</i> Koch 1873
<i>Aname pellucida</i> Hogg 1901	= <i>Stanwellia grisea</i> (Hogg 1901)
<i>Aname pexa</i> Hickman 1929	= <i>Stanwellia pexa</i> (Hickman 1929)
<i>Aname pulchra</i> Rainb. & Pull. 1918	= <i>Dyarcyops pulchellus</i> (Rainb. & Pull. 1918) (†)
<i>Aname robusta</i> Rainb. & Pull. 1918	= <i>Dekana grandis</i> (Rainb. & Pull. 1918)
<i>Aname tasmanica</i> Hogg 1902	= <i>Aname tasmanica</i> Hogg 1902
<i>Aname villosa</i> Rainb. & Pull. 1918	= <i>Aname villosa</i> Rainb. & Pull. 1918
<i>Aname platypus</i> (L. Koch in Ausserer 1875) (‡)	= ?

Note: The types of all the above species (except *Brachythele platypus* Koch, *Aname bicolor* Rainbow and *Aname pexa* Hickman) have been seen by the author.

(\*) Synonymy noted by Rainbow (1918) and Hickman (1964)

(†) New combination; originally described as *Arbanitis pulchellus* Rainbow and Pulleine 1918

(‡) Originally described as *Brachythele platypus* L. Koch in Ausserer 1875

Along with deliberate attempts to establish male/female associations of species on biological grounds, all extant types of Australian Mygalomorphae have been traced and most of these have been examined by the author. As a result it has been possible to make valid groupings of species into genera, which may now be more clearly defined.

### Taxonomy of Diplurinae

The main purpose of the present paper is to discuss *Stanwellia* as distinct from other diplurine genera. Diplurine spiders are distinguished from the other sub-families of the Dipluridae by having two pairs of spinnerets and the paired tarsal claws bipectinate. They are generally large, dark coloured spiders and live in burrows in the ground or sometimes in silk tubes in rotten logs or moss and friable bark on the boles of trees. The following genera have been recorded from Australia: *Chenistonia*, *Dekana*, *Ixamatus*, *Aname*, *Stanwellia*, *Kiama* and *Sungenia*. The genus *Troglodiplura* described from the dried fragments of a single specimen found in a Nullarbor cave is possibly a 'fossil' genus. The present author tentatively regards *Sungenia* as a synonym of *Chenistonia*.

#### Status of the genus *Aname*

The holotype of *Aname pallida* Koch, which is the type species of *Aname* Koch, is lodged in the Hamburg Museum, Germany (sighted by the author in 1958). It was obviously a freshly moulted specimen when collected, hence the unpigmented or "pale" colour.

#### ANAME Koch 1873

*Aname* Koch, 1873. Die Arachniden Australiens, p. 465. Type species by original designation *A. pallida* Koch, 1873. *ibid.* p. 465-7. Pl. xxxv, F.8 Type locality: Bowen, Queensland. Collector probably Amelia Dietrich.

#### Description of holotype of *Aname pallida*

Although badly macerated the following features were recognisable:

Carapace length 6.5 mm; procurved fovea; eyes on a pronounced tubercle set back from margin and anterior row distinctly procurved (fig. 1); sternum badly distorted, posterior sigilla away from margin, misshapen but broadly oval (fig. 2). Labium broad, anteriorly indented and without cuspules or spines; cuspules on maxillae; chelicerae with teeth on promargin of furrow only, no apical teeth (i.e. no pseudo-rastellum). The palpal tarsus was swollen indicating that the specimen was an immature male; a pair of basal spines. Scopula present on palpal tarsus, and tarsi and metatarsi of legs I and II, a few scopulate hairs on tarsi III and IV. *Spines*. Tarsi of all legs without spines. I, Metatarsus ventral spines; Tibia ventral bristles. II, Metatarsus ventral spines; Tibia ventral spines and bristles. III, Metatarsus with spines on all faces; Tibia ventral and dorsal spines. IV Metatarsus with spines on all faces; Tibia ventral bristles and dorso-retrolateral spines; all femurs with dorsal bristles. Paired tarsal claws bipectinate. Abdomen macerated but appeared dorsally to have been of uniform colour.

From the above, a diagnosis of the genus *Aname* can be made as follows:

Carapace with procurved fovea; eyes on pronounced tubercle; labium broad and anteriorly indented, without cuspules; cheliceral furrow with teeth on promargin only; no pseudo-rastellum; posterior sternal sigilla away from margin (possibly variable); a proximal pair of ventral spines on palp tarsus; no spines on tarsi of legs; scopula on tarsi of palp and at least tarsi I and II.

#### Relationship of *Aname* to other diplurine genera

Thus *Aname* on the above characters can be distinguished from *Chenistonia*, which has a straight fovea and long narrow posterior sternal sigilla (F. 3) and possibly from *Dekana*, which although usually with a procurved fovea has narrow elongate posterior sternal sigilla. It has been observed that specimens attributable on morphology (not considering the doubtful feature of sternal sigilla) to either *Dekana* or *Aname* can be distinguished in life by the type of burrow constructed. *Dekana* specimens (males and females) build a forked (wish-bone or Y-shaped) burrow with only one arm of the fork opening completely on the surface; specimens which build a simple, unbranched burrow have been attributed to *Aname*. Both groups are widely distributed throughout Australia. *Dekana* has probably been derived from *Aname*. However, in the absence of an authentic male, the features listed above, alone, would not unequivocally distinguish *Aname* from *Ixamatus*, the type locality of whose type species is also allegedly Bowen, Queensland. The male of *Ixamatus* has no tibial spur on the first leg, *Chenistonia* and *Dekana* have a spur (fig. 4). The female of *Stanwellia* differs from *Aname*, and all other known Australian diplurines, by having no spines on the palp tarsus (figs. 7, 7a).

Since at least nineteen of the subsequently described twenty-five species of *Aname* can readily be attributed to various other named and more clearly defined genera (although of later erection) the genus *Aname* itself is thus reduced in size (see Table 1). The rationale for transferring the various species of *Aname* to other genera (see Table 1) will be discussed along with the appropriate genus (Main in preparation).

By inference, species in eastern Australia (with the exception of certain undescribed forms which do not have leg scopula on the females) which do not by definition fall into *Dekana*, *Chenistonia*, *Ixamatus* or *Stanwellia*, might well be left in *Aname* or transferred to *Aname* from other genera. The definition of *Aname* could then be enlarged to include the following characteristic: male with spine-bearing spur on tibia I. This has been deduced from the observation that there are in fact diplurine species in coastal and mountainous Queensland, the females of which could be attributed to either *Aname* (as defined above) or *Ixamatus*, but in which the males have a tibial spur, thereby excluding them from *Ixamatus*.

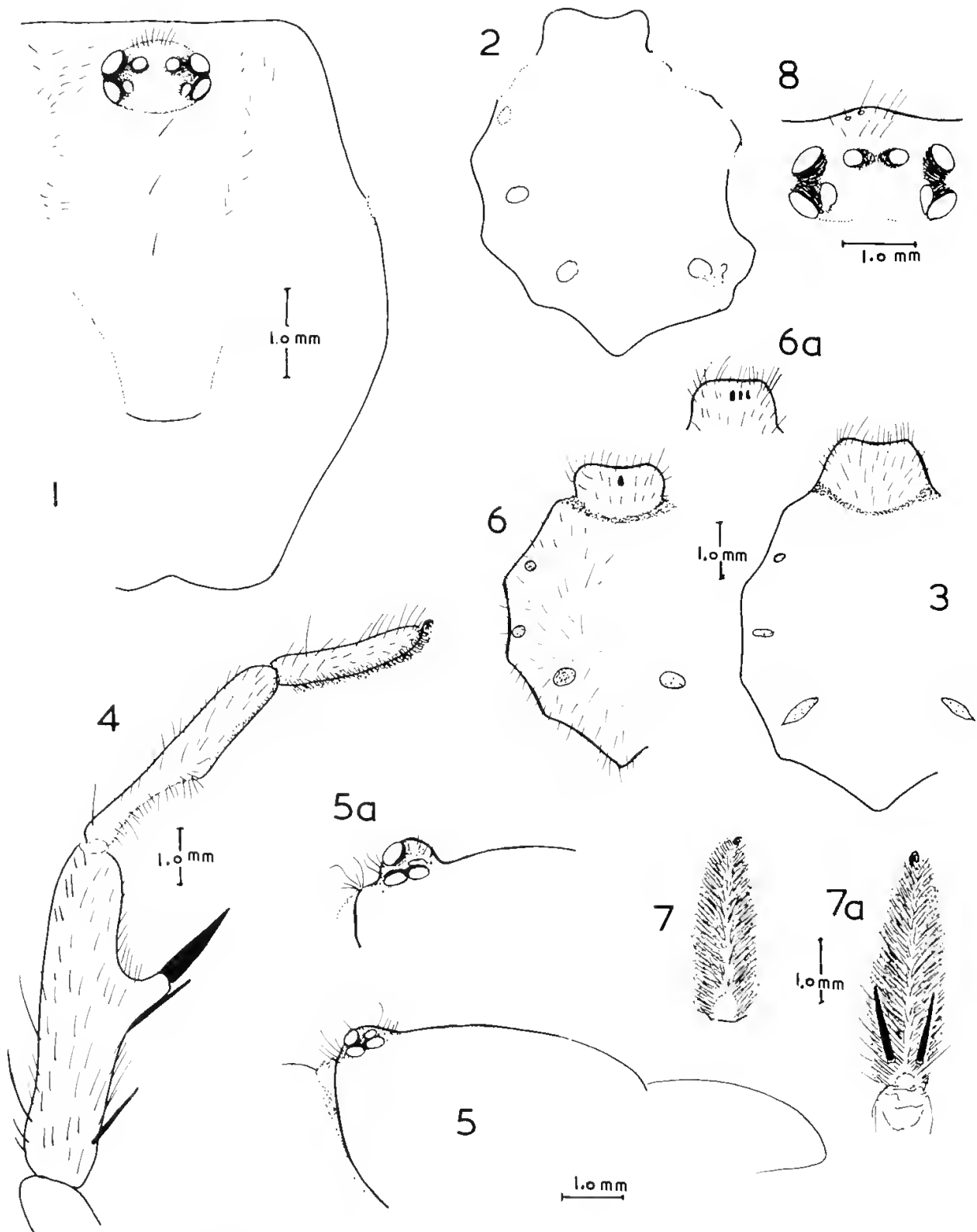
The recently described genus *Kiama* (Main and Mascord 1971) is distinguished from the

above genera as follows: from *Chenistonia*, *Dekana* and *Aname* by the absence of a tibial spur in the male and the presence in the female of several ventral spines instead of a basal pair on the palp tarsus; it differs from all the other diplurine genera in the deeply procurved U-shaped fovea and broad sternum with large,

tear-drop shaped sigilla and from all genera (except an undescribed form in the MacPherson Range) by having no leg scopula in the female

# **STANWELLIA** Rainbow and Pulleine 1918

*Stanwellia* Rainbow & Pulleine, 1918. Rec.Austr. Mus. 12: 164. Type species by monotypy *Stanwellia decora* Rainbow & Pulleine 1918 = *Stanwellia hoggi* (Rainbow 1914).



Figures 1-8.—1, 2. *Aname pallida* Koch, Holotype. 1, carapace, note eyes and fovea; 2, sternum, damaged and shape distorted. 3(♀), 4(♀), 5a(♀), *Chenistonia*. 3, sternum and labium; 4, right leg I, retrolateral view, note tibial spur; 5a, profile of eye tubercle. 5, 6, 6a, 7, 8, *Stanwellia*. 5, profile of eyes; 6, sternum and labium; 6a, labium of another specimen with more cuspules. 7, ♀ palp tarsus, ventral; 8, *S. decora* Rainbow and Pulleine, lectotype, dorsal view of eyes [= *S. hoggi* (Rainb.)]. 7a, *Chenistonia*, ♀ palp tarsus, ventral.

### Description

*Carapace* long and narrow, roughly a truncated oval; caput low. *Fovea* shallow, straight or very slightly procurved. *Eyes* raised but not on a distinct tubercle, group broader than long (fig. 5). *Sternum*, long and narrow; sigilla usually small and submarginal (fig. 6).

*Labium* broad, anteriorly straight or only slightly indented, usually with a few anterior cuspules (fig. 6, 6a).

*Chelicerae* with continuous row of teeth on promargin of furrow only, with a small basal group on retromargin; sometimes with teeth or stout bristles (like a rastellum) above fang base (fig. 29). Palp tarsus without spines (fig. 7), scopula present, claw with prolateral row of teeth only. Legs, no spines on anterior two pairs of tarsi. Scopula present on tarsi I and II and apical part of metatarsi I and II, usually present on tarsi III, present or absent on tarsi IV. Legs often with pattern of dark blotches or annulations. Abdomen usually with speckled pattern or irregular bands consisting of a dark, median branched area (approximating to the heart outline) with laterally, an irregular pattern of yellow patches. Two pairs of spinnerets, terminal joint of posterior pair elongate and pointed. Tibia I of male with spines but no spur (figs. 9, 15, 19, 21, 26, 35 and 42). Palp tibia with few or no spines. Stigma broad and flanged, with embolus extending as a point at tip. No clear demarcation between stigma and bulb.

### Diagnosis

No spines on female palp tarsus; eyes may be raised but not on a tubercle; posterior sternal sigilla small, often round, sub-marginal; truncate labium usually with cuspules; characteristic dark "smudges" or speckled pattern on legs in life. Male lacks spur on tibia I; stout, broad palpal stigma indistinctly demarcated from bulb. Female internal genitalia with either two large basal mound-like areas with ducts leading to small vesicles or a single basal area from which the vesicle stalks arise.

### Affinities

Very similar to the New Zealand genus *Aparua* from which it is distinguished by the latter having a double row of teeth on the female palp claw.

The genus has no close affinity with any other Australian genus.

The present author recognises the following six species: *Stanwellia hoggi* (Rainbow), *S. grisea* (Hogg), *S. paxa* (Hickman), *S. nebulosa* (Rainbow and Pulleine), *S. occidentalis* sp. nov. and *S. inornata* sp. nov. Additional specimens, the specific status of which is undecided, have also been collected by the author from several localities.

### *Stanwellia hoggi* (Rainbow 1914)

*Chenistonia hoggi* Rainbow 1914. Rec. Austr. Mus. 10: 240-2.

*Stanwellia decora* Rainbow & Pulleine 1918. Rec. Austr. Mus. 12: 164-5.

*Aname decora* Rainbow and Pulleine 1918. Rec. Austr.

Mus. 12: 149-150. HOMONYM.  
*Stanwellia decora* Rainbow and Pulleine in Main "Spiders of Australia" (Jacaranda 1964, 1967).

### Types

Holotype of *Chenistonia hoggi* Rainbow: female from North Sydney (Australian Museum K31010).

"Type" of *Stanwellia decora* Rainbow and Pulleine: Female from Stanwell Park, Australian Museum K40955, herein designated as the lectotype.

"Cotype" female, *S. decora* from Stanwell Park N.S.W., Aug. 1910, in the South Australian Museum, herein designated as paralectotype.

Holotype female, *Aname decora* Rainbow and Pulleine. Clifton Gardens, Sydney (Australian Museum K 40923).

### Notes on synonymy

Since by transferring the species *Aname decora* Rainbow and Pulleine to *Stanwellia* this name becomes a homonym of *S. decora* Rainbow and Pulleine, it should be replaced by another name. However since *A. decora* is here regarded as a synonym of *S. decora* this is not necessary. Although *A. decora* has precedence in the same publication over *S. decora*, under the provisions of Article 24a of the International Code for Zoological Nomenclature, it is justifiable to give priority to *S. decora*. Furthermore both *A. decora* and *S. decora* are junior synonyms of *Chenistonia hoggi* Rainbow.

### Description of lectotype of *Stanwellia decora* Rainbow and Pulleine.

*Carapace*, length 9.0 mm, width 7.7. *Fovea* slightly procurved. *Eyes* raised, length of group 0.85 mm, width 1.85 mm, anterior row almost straight in front, very slightly procurved (fig. 8).

*Chelicerae*, left paturon with one small and nine large teeth on promargin, about 21 in basal posterior cluster.

*Labium*, length 1.0 mm, width 2.0 mm, 2 cuspules.

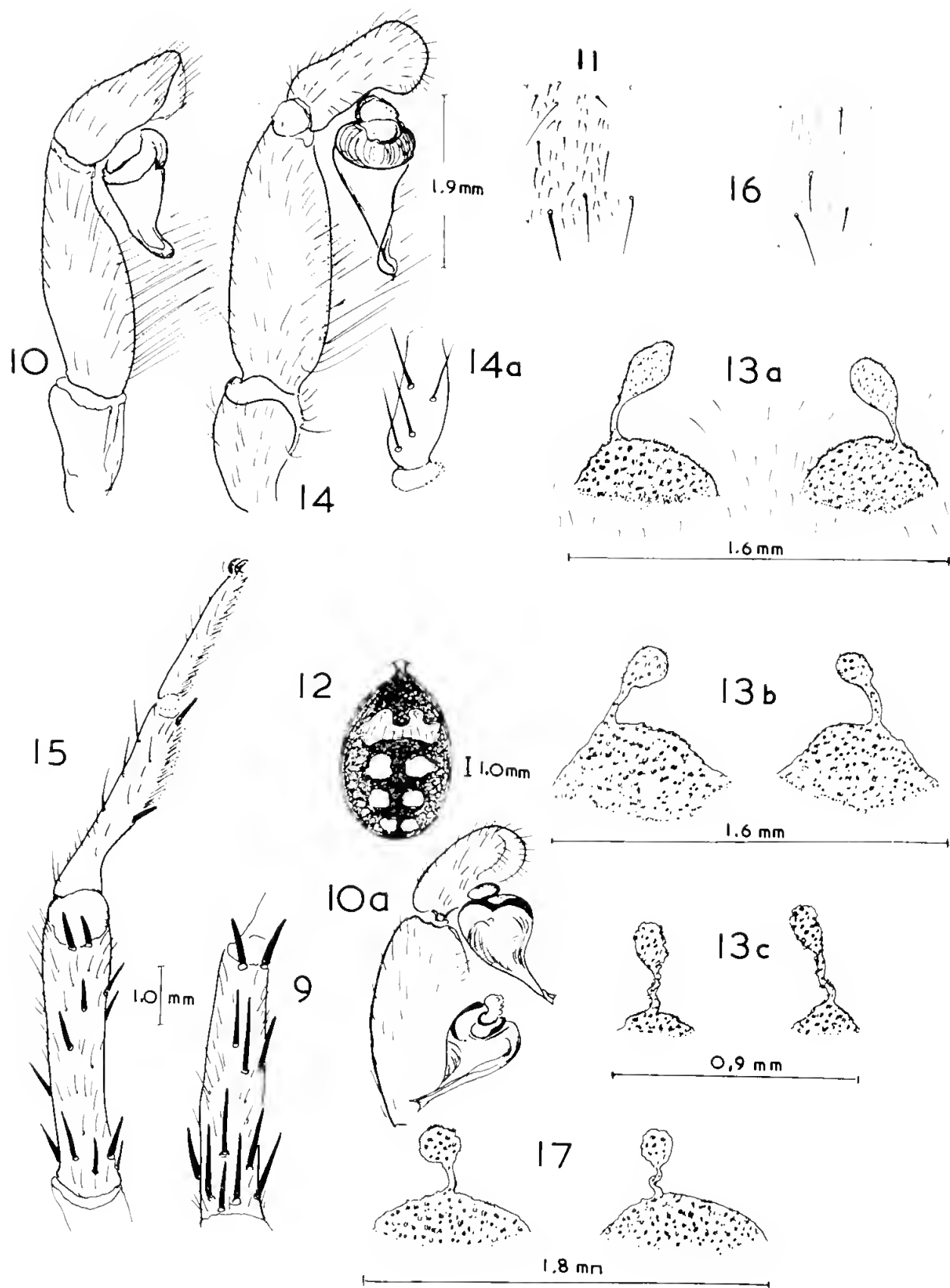
*Sternum*, length 5.0 mm, width 4.1 mm, Posterior sigilla small oval, submarginal.

*Legs*: Scopula complete on all tarsi and metatarsi I and II, apical half of metatarsi III and a few apical hairs on metatarsi IV

Leg formula	4	1	2	3		
	3.14	2.91	2.68	2.36		
	F	P	Ti	Mt	Ta	Total
Palp	5.0	2.6	3.5		3.4	14.5 mm
I	7.6	4.6	5.3	5.0	3.7	26.2 mm
II	6.8	4.5	4.8	4.5	3.6	24.2 mm
III	5.8	3.6	3.6	4.8	3.5	21.3 mm
IV	7.5	4.1	6.2	7.0	3.5	28.3 mm

Width patella I at knee = 1.5, Tibial index = 15.15  
Width patella IV at knee = 1.5, Tibial index = 14.56





Figures 9-17.—9, 10, 10a, *S. hoggi* (9, 10 specimen in Hope Museum). 9, right tibia I, ventral; 10, right palp, retrolateral; 10a (Kiama specimen) right palp (Australian Museum KAI). 11, 12, 13a b c, 14, 14a b, 15, *S. Grisea* (Hogg). 11, mid-dorsal abdominal pilosity (number of hairs and bristles in area 1.0 mm across). (BYM 65/11); 12, dorsal abdominal pattern (BYM 65/32); 13a, b, c, ♀ internal genitalia (BYM 65/11, 65/16, 65/693 respectively); 14, right palp retrolateral, 14a, tibia prolateral (BYM 65/27); 15, right leg I, prolatero-ventral (BYM 65/27); 16, 17, *S. nebulosa* (Rainbow). 16, abdominal pilosity (BYM 59/425); 17, ♀ internal genitalia (BYM 59/425).

*Spines*: Absent from all tarsi, including palp. Present on following segments:

- I, Metatarsus, 3 ventral; Tibia, 4 ventral, 2 prolateral; Femur, 1 dorsal.
- II, Metatarsus, 4 ventral, 1 prolateral; Tibia, 6 ventral bristles, 2 prolateral; Patella, 1 dorsal; Femur, dorsal? (detached).
- III, Metatarsus, 6 ventral, 6 dorsal, 2 prolateral, 1 retrolateral; Tibia, 6 ventral bristles, 2 prolateral, 2 retrolateral; Patella, 3 prolateral; Femur, 3 dorsal bristles.
- IV, Metatarsus, 7 ventral, 6 dorsal, 4 prolateral, 1 retrolateral; Tibia, 6 ventral, 2 retrolateral; Femur, dorsal bristles.

Palp, Tibia, 4 apical spines, also 4 sockets where spines or bristles have been removed.

*Abdomen*: Brownish colour with yellow mottlings, about 12.00 mm long.

#### *Specimens examined*

*Types and other specimens named by Rainbow*: Lectotype, Paralectotype and three other specimens labelled as *Stanwellia decora* by Rainbow: two Females (K40958) and one immature (K41456), all from Stanwell Park August 1908, (examined by present author in 1954); these specimens agree generally with the lectotype. Holotype of *Aname decora* Rainbow & Pulleine, and holotype of *Chenistonia hoggi* Rainbow.

*Other specimens*: Males. Two previously unidentified male specimens in the Hope Museum, Oxford, collected from Sydney in 1869; one of these specimens with four labial cusps, ten ventral spines on tibia I (fig. 9) and palp with bluntly pointed stigma (fig. 10); no spines on palp tibia.

A male specimen (Australian Museum KA1) collected by R. Mascord from Kiama, N.S.W., 22 June, 1965. The specimen was found wandering at night near burrows of *Dyarcyops* with which genus it was at the time identified. The specimen has a carapace length of 7.7 mm, marginal bristles present; labium with four labial cusps; abdomen with four pairs of yellowish blotches on dark brown background; colour generally dark brown with golden sheen. The palp tibia and stigma as figured (fig. 10a); right palp with no prolateral spines on tibia, left palp tibia with two delicate prolateral spines. Ten ventral spines on tibia I, but with different disposition on the left and right legs.

Leg formula

4	1	2	3
3.36	3.07	2.87	2.66
Tibial index I	12.35; Tibial index IV	12.50	

#### *Stanwellia grisea* (Hogg 1901)

*Aname grisea* Hogg, 1901. Proc. Zool. Soc. London, 1901 (vol. 2): 252-254, fig. 30.  
*Stanwellia grisea* Main: "Spiders of Australia" (Jacaranda 1964, 1967).

#### New synonymies:

*Aname arborea* Hogg, 1901. Proc. Zool. Soc. London, 1901 (vol. 2): 254-5, fig. 31.  
*Aname pellucida* Hogg, 1901. ibid pp. 255-6, fig. 32.  
*Ixamatus gregori* Hogg, 1901. ibid pp. 258-9, fig. 33.  
*Chenistonia major* Hogg, 1901. ibid pp. 263-4, fig. 36.  
*Aname butleri* Rainbow & Pulleine 1918. Rec. Austr. Mus. 12: 157-8, fig. 112. (Lectotype only; see note below on types).

#### *Notes on types and synonymies*

*Aname grisea*, *arborea*, *pellucida*, *Ixamatus gregori* and *Chenistonia major*, all in British Museum (N.H.) and all seen by the author in 1958:

*Aname grisea*: The "type" series (30.2.10-15) consists of three juvenile specimens, the largest (which is here designated as lectotype) with carapace length of 4.0 mm. All are pierced longitudinally with pins but are now in spirit. Locality, Macedon, Victoria (Hogg 1901).

*Aname arborea*: A female (herein designated as lectotype) and juvenile in the one tube (03.2.10-17); female with carapace length of 5.5 mm. Locality, Macedon (Hogg 1901).

*Aname pellucida*: Labelled 'type' and 'collected at Bacchus Marsh' (03.2.10-16). The tube contains a juvenile specimen and badly damaged female with carapace length of 8.0 mm which is herein designated as lectotype.

*Chenistonia major* (03.2.10.7.8): Seven females, with carapace lengths of 4.0 mm, 8.0, 10.0 (3 specimens), 10.5, 11.0 mm (the latter designated as lectotype). Locality, Macedon.

The specimens described by Rainbow and Pulleine (1918) as males of *Chenistonia major* Hogg (two specimens in the one tube, labelled "allotype" K40968. Australian Museum) are not the same species as the specimens named by Hogg (1901) as *Chenistonia major* (here synonymised with *Stanwellia grisea* (Hogg) but are the previously undescribed males of *Chenistonia tepperi* Hogg. Also, in the South Australian Museum there are two male specimens labelled "cotype ♂, *Chenistonia major* Hogg ♂, Mordialta Gully S.A.", these are thought to be from Rainbow and Pulleine's collection. They are not *Stanwellia* specimens but either *Chenistonia* or *Dekana*.

*Ixamatus gregori*, a single adult male specimen (1903.2.10.14), labelled "type" which is therefore the holotype. Locality, Macedon.

*Aname butleri*, Australian Museum (K41482) and seen by the author in 1954. It is labelled 'type' and the locality is Merri Creek, Melbourne. I herein designate it as lectotype. This specimen (lectotype) is not a female but (as deduced from the swollen palps) an immature male. In the Australian Museum there are four additional females labelled as *Aname butleri* (K41614, also labelled "type" (one specimen) and K41615, labelled "co-types" (three specimens)). These four specimens are not Diplurids but Ctenizids and I regard them as *Dyarcyops*. With K41614 there is another label stating:—"this is not holotype (D. R. McAlpine 22.8.52)."

#### *Diagnosis*

*Female*: Colour in life generally a dark brown; dorsum of abdomen with short, sparse pile (fig.

11), pattern of yellow mottlings on dark background, variable, may be of uniform 'speckles' or consist of lateral yellow blotches alongside a dark median section overlying the heart (fig. 12), sometimes posteriorly with dark bands; venter usually uniformly pale or with dark flecks; legs paler usually with dark blotches, sometimes with distinct annulations. Carapace low, caput rounded. Labium with variable number of cusps, two to six. Carapace length of specimens measured, up to 9.7 mm.

Leg formula of a specimen with carapace length of 7.2 mm (Mount Macedon, BYM 65/16):

4	1	2	3
2.93	2.47	2.32	2.12

Tibial index I, 15.71; tibial index IV, 15.38.

Internal genitalia consist of two broad denticulate basal structures which, when viewed dorsally, appear as two mounds but which are in fact the mouths of two funnels leading into the 'spouts' or narrow ducts connected with the blind vesicles (figs. 13a, b and c).

Male (see fig. 42). Palp and tibia I (BYM 65/27) as figured (figs. 14 and 14a and 15). Carapace with dense marginal bristles. Differs from *S. pexa* and *S. nebulosa* by having more spines on prolateral aspect of palpal tibia. Carapace length of holotype of *Iramatus gregori* (= *S. grisea*) 4.0 mm, and of two specimens of *S. grisea* collected by the author, 7.3 (BYM 65/23) and 7.5 mm (BYM 65/27).

Leg formula BYM 65/27.

4	1	2	3
3.2	3.03	2.89	2.45

Tibial index I = 13.58, Tibial index IV = 14.63.

#### Specimens examined and localities

Types as listed above and the following specimens (collected by the author except where otherwise stated).

**Females and juveniles:** 20, Macedon, V.; Grampian Mountains, V. 5, Barney's Creek; 1, Dairy Creek Road; 1, Stony Creek Road, about two miles from Silver Band Falls; 1, Mt. Victory Road; 2, Chataqua Park Road; 1, Mt. William Road (near top); 1, Mt. William Road, near turnoff; 4, three miles east of Myrtle Bank. Dandenong Range: 6 and one brood, Ferntree Gully, half a mile from station; 4, Sassafras Road; 1, Highett, V. (collected by E. Swarbreck and sent to the author by Professor Hickman who had labelled the specimen *Aname butleri*).

**Males:** 2, Macedon, V. These two specimens collected as penultimate instar males on 12.ii.1965 and held in flowerpots of soil. They moulted to maturity late February/early March.

#### Natural history

The spiders have a simple open burrow, with sparse silk lining. The burrows are made in damp situations of the forest floor, in deep humus and moss or amongst leaf litter. They often occur in undisturbed, wet road banks. The species appears characteristically to inhabit gullies of mountainous areas and fringes of

swampy areas where the soil is fairly well drained. Some have been found in moss and bark at the base of tree trunks.

#### *Stanwellia nebulosa* (Rainbow and Pulleine 1918)

*Aname nebulosa* Rainbow & Pulleine, 1918. Rec. Austr. Mus. 12: 147-8.

*Stanwellia nebulosa* (Rainbow & Pulleine) in Main, "Spiders of Australia" (Jacaranda 1964, 1967). New syn. *Aname confusa* Rainbow and Pulleine, 1918. Rec. Austr. Mus. 12: 155-7.

#### Notes on Types

Male "type" of *Aname nebulosa*, (Australian Museum, K40924), Mallala, S.A., 23.iv.1905. The collection date of this specimen is given as March 23 in Rainbow and Pulleine (1918).

The description of the male specimen precedes that of the female, therefore the male 'type' is herein designated as the lectotype of the species *Stanwellia nebulosa* (Rainbow and Pulleine).

♀ "type" of *Aname nebulosa*, Tea Gardens, Mt. Lofty, S.A., 4.xi.17, (Australian Museum K40926).

2♀♀ ("cotypes") (Austr. Mus. K41460), Mallala, S.A.; ♀ ("cotype") (Austr. Mus. K40930), McIngal, S.A., May 1908, [date given as 'July 1917' by Rainbow and Pulleine (1918)]. Specimens numbered as follows: Australian Museum K40926, K41460 (2 specimens), and K40930 are herein designated as paralectotypes. They were sighted by the author in 1954. ♀ 'cotype' *Aname nebulosa*, Aldgate S.A. May 24, 1910, in the South Australian Museum (sighted by the present author in 1952) and herein designated as a paralectotype. Rainbow and Pulleine (1918) also mention a specimen from "Scott's Creek" of which the whereabouts is not known.

#### Diagnostic description

**Female:** General appearance as in Fig. 43. Carapace length of paralectotype (Australian Museum K40926) 8.7 mm; leg formula:

4	1	2	3
2.71	2.27	2.27	1.94

Tibial index I, 15.78; tibial index IV, 15.38.

In life specimens are a dark, dusty brown with golden hairs and a yellow, speckled pattern on abdomen dorsum, legs paler with dark smudges. Abdomen with dorsal pile of fine hairs (fig. 16).

Internal genitalia as figured (fig. 17); similar to *S. grisea* and *S. pexa*.

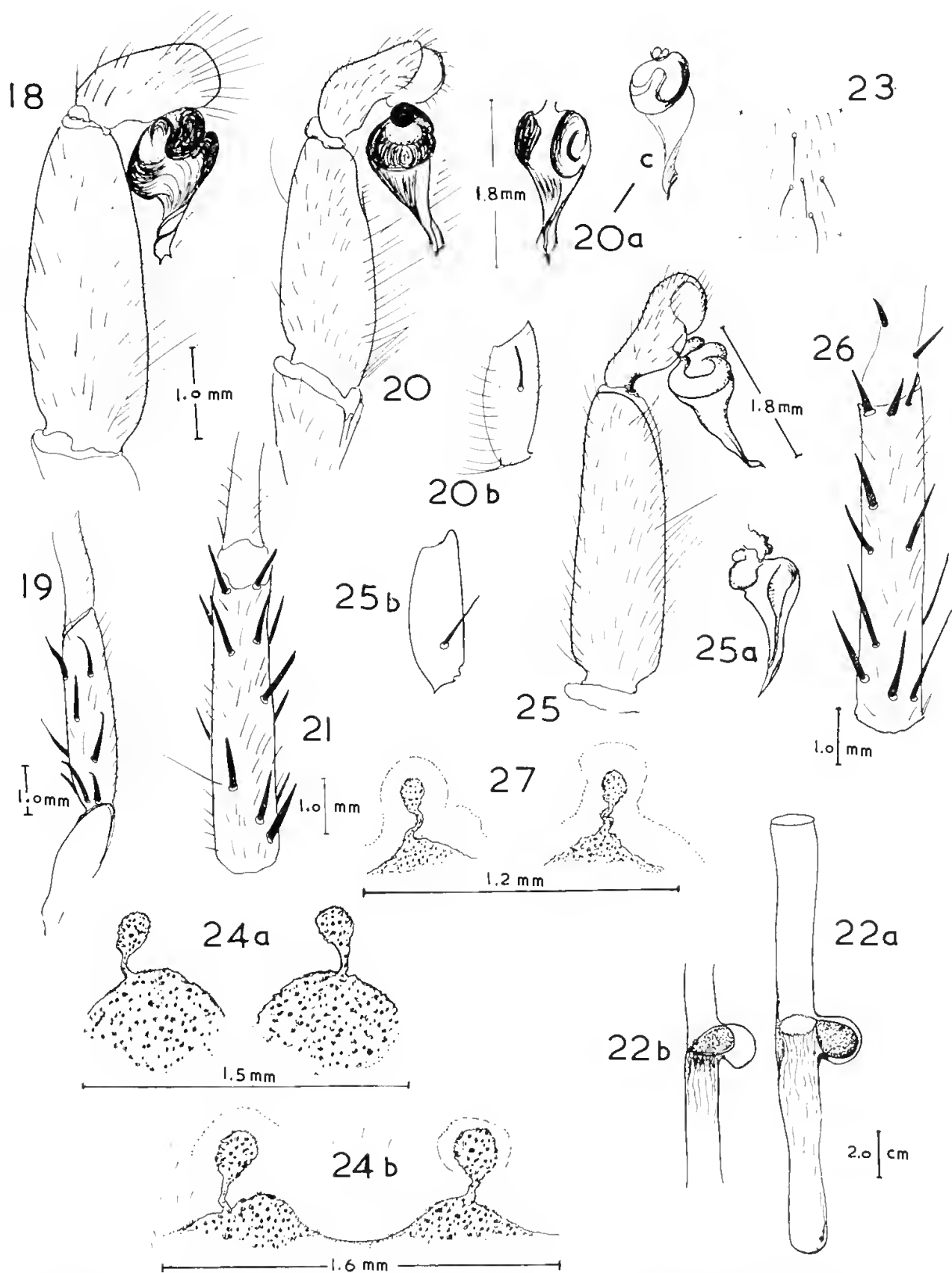
**Male:** Palp and tibia I as figured (figs. 18, 19 & lectotype, figs. 20, 21 of BYM 54/547). Stigma long and bluntly pointed at tip; palp tibia with one large stout prolateral spine in mid region, one spine absent. Tibia I with eight ventral spines. Carapace length of lectotype 5.3 mm; carapace length BYM 54/547, 8.0 mm. The legs of the lectotype were damaged but the leg formula of BYM 54/547 is as follows:

4	1	2	3
3.93	3.60	3.52	3.10

Tibial index I = 11.11, Tibial index II = 11.90.

#### Specimens examined and localities

Types as above and the following specimens collected by the author (except where otherwise stated):



Figures 18-27.—18-22, *S. nebulosa*. 18, 19, lectotype. 18, right palp, retrolateral; 19, right tibia I, prolateral; 20, right palp retrolateral (BYM 54/547); 20a, c, different aspects of stigma (fig. 20c shows the same aspect as in fig. 18), 20b prolateral view of tibia; 21, ventral view right tibia I (BYM 54/547); 22a, b, longitudinal section of burrow, showing "open" position of 'pebble' in side pocket (a) and in 'closed' position (b). 23-27, *S. pera* (Hickman). 23, 24a, (♀ specimen from Queens Domain, Tasmania, V.V.H. BYM 70/38); 23, abdominal pilosity; 24a, internal genitalia. 24b, ♀ internal genitalia (BYM 54/65); 25, a, b, palp retrolateral view, a, stigma rotated, b, tibia prolateral aspect (BYM 54/66); 26, tibia I ventral (BYM 54/66); 27, ♀ internal genitalia (BYM 70/36) (Tasmania W. coast near mouth Arthur R., V.V.H.)

**Females and juveniles:** South Australia: 1, Aldgate; 3, Bute; 4, Blackwood (including 1 penultimate instar ♂); 8, Blanchetown; 1, Dublin; 3, Willunga Hill, Kuitpo; 1, Nairne; 2, Port Broughton, 8 miles south; 1, Port Germain Gorge; 1, Tarlee; 2, Tintinara, 2 miles south; 1, Mount Lofty; 2, Stirling; 6, Wirrega, Victoria: 3, Nhill, 10 miles west (east of Lowlait Ranges). One female forwarded by Professor Hickman. This specimen was collected by Dr. R. H. Pulleine and the locality given only as "South Australia".

**Male:** Specimen BYM 54/547 was collected as an immature specimen from Willunga Hill, Kuitpo, S.A., on 18 December, 1954. The specimen was not obviously a male and was kept for observation in a flowerpot of soil in which it made a characteristic burrow. It was found to be mature on 2 April, 1956.

#### Natural History

The spiders build a distinctive vertical burrow. The entrance may have a small collar of leaves but the upper section is unwebbed. The lower half is silk-lined. A pear-shaped pebble made by the spider of compacted soil is attached to one side of the free, collar-like upper part of the silk lining. The pebble is so counter-weighted, that when the spider is disturbed and pulls on the silk collar, it falls across and blocks the burrow lumen (see figs. 22a, b). Rainbow and Pulleine (1918, pp. 82-3, pl. 20) originally described this curious structure, and Main (1964, 1967, pp. 44, 45) again figured and described it. Specimens in captivity have also been observed constructing the characteristic burrow.

The species generally occurs in drier situations than do the eastern species. It extends from damp situations in gullies of the Lofty Mountains near Adelaide, eastward into the dry limestone soils of the mallee region of south-eastern S. A. and western Victoria and northwards through the Flinders Range to Port Augusta.

#### *Stanwellia pexa* (Hickman 1929)

♀ *Anane pexa* Hickman, 1929. Proc. Roy. Soc. Tasmania, 1929, 87-97, figs. 1-6.

#### Types

Queen Victoria Museum, Launceston, Tasmania.

Type locality, Prince of Wales Bay, Derwent Park (not seen by the present author). The male description precedes that of the female and is herewith designated as the lectotype, and the female as paralectotype.

Hickman in his description of the female (Hickman, 1929) states the claw of the female palp "with a double row of teeth". However, I noted that on a specimen sent by Professor Hickman to the British Museum (Natural History) teeth were present only on the prolateral side of the palp claw (B. M. (N. H.) Register No. 1931. 70.30.51). Professor Hickman (in litt.) has now confirmed that his original statement was in error and that *S. pexa* has only a single row of teeth on the palpal claw.

**Female:** Dark coloured and with conspicuous markings on legs, abdomen irregularly mottled or banded. Sparse pile of fine hairs and bristles

(fig. 23). Internal genitalia similar to *S. grisea* and *S. nebulosa*. The basal funnels may be large (fig. 24a) or small (fig. 24b). Specimens with carapace length up to 12.9 mm.

**Male:** Palp and tibia I as figured (figs. 25, 26), specimen from Fisher Island (BYM 54/66). The palpal stigma is generally relatively longer and more tapering than that of other species. Carapace length of mature males is variable: male type 7.0 mm. (Hickman 1929); male from The Domain, Hobart, Tasmania, 7.0 mm; of four males from Fisher Island, carapace lengths as follows: 8.7, 9.0, 9.7 and 10.00 mm. Leg formula and tibial indices of BYM 54/66.

4	1	2	3
3.57	3.36	3.26	2.84

Tibial index I = 12.17, Tibial index IV = 12.82  
Leg formula of male type [calculated from Hickman's measurements (Hickman 1929, pp. 87-8)].

4	1	2	3
3.26	2.87	2.78	2.43

Tibial index I, 14; tibial index IV, 14 (Hickman 1929).

#### Specimens examined and localities

1♀ British Museum specimen. 6♀♀, 4♂♂ Fisher Island (collected by V. N. Serventy); 2♀♀ from Queen's Domain, Hobart and 1♂ from The Domain Hobart, Tasmania (collected by V. V. Hickman); 3♀♀ from north of mouth of Arthur River, west coast Tasmania (collected by V. V. Hickman), tentatively identified as *S. pexa*, internal genitalia of one specimen as in fig. 27 (BYM 1970/36).

#### Natural History

Hickman (1929) described the burrow as being vertical with a collar of grass stalks at entrance and with a swelling near base, the whole with only a sparse lining of silk. Burrows were up to 15.0 cms. deep and were in a bank about ten yards from the sea-shore in a patch of scrub. V. N. Serventy reported (personal communication) that vertical and oblique burrows, all without any closure, were constructed by specimens on Fisher Island.

#### *Stanwellia occidentalis* sp. nov.

#### Types

Holotype ♀, mouth of the Todd River north of Port Lincoln, Eyre Peninsula, South Australia, collected by B. Y. Main, 16 December, 1952 (BYM 52/533). Australian Museum No. K69302.

Paratype ♀, Cummins Plains, east of Cummins, Eyre Peninsula, S.A., collected by B. Y. Main, 16 December, 1952 (BYM 52/561). Specimen with young in burrow. Australian Museum No. K69301.

Paratype ♀, Cummins, 8 miles east, Eyre Peninsula, S.A., collected by B. Y. Main 17 December, 1952 (BYM 52/575), South Australian Museum No. N19719.

#### Description of holotype

**Female** (fig. 28). Carapace glabrous, dark brown, almost straight sided. Legs pale coloured with dark brown blotches and annulations as

follows: I and II, femur with proximal and distal annulation; patella distal annulation; tibia, proximal and distal annulation; metatarsus and tarsus, pale with dark smudges; III and IV, faint annulations on femur, patella tibia, pale coloured metatarsus and tarsus. *Carapace* 3.9 mm long, 2.9 mm wide, caput 2.3 mm wide. *Fovea* almost straight, slightly procurved. *Abdomen* 6.0 mm long, 3.8 mm wide, almost straight-sided. *Sternum* 1.9 mm long, 1.6 mm wide, sigilla indistinct (fig. 29). *Labium* 0.5 mm long, 0.65 mm wide, 1 cuspule. *Maxillae* with about 16 cuspules. *Chelicerae*, promargin of groove with 7 teeth, a basal outer cluster of about 15 granules. *Rastellum* of heavy teeth above base of fang, and around apical angle (fig. 29); teeth not on a process. This rastellum is as pronounced as in many Ctenizidae, for example as in *Dyarcops*.

*Spines*. Palp, tibia 8 ventral. I, metatarsus 4 ventral, 1 prolateral; tibia, 3 retroventral. II, metatarsus, 5 ventral, 1 dorsal; tibia, 3 (bristle-like) ventral. III, metatarsus, 4 ventral, 5 dorsal, 3 prolateral; tibia, 3 dorsal, 2 prolateral; patella, 3 stout prolateral (like a Ctenizid). IV, metatarsus, 7 ventral, 3 dorsal, 1 prolateral; tibia, 1 apical ventral.

*Scopula* complete on tarsi I and II and palp and metatarsus I; apical hairs on metatarsus II, absent on third and fourth legs. *Trichobothria* few, up to 6 or 7 in dorsal irregular line on tarsus, metatarsus and tibia.

Leg formula 4 1 2 3

2.46 2.35 2.1 1.74

Tibial index I, 14.28; tibial index IV, 15.78.

*Abdomen* oval, almost straight sided with a dark median area, otherwise a uniformly mottled pattern of yellow flecks. Sparse pile of hair. Terminal segment of posterior spinnerets relatively short and pointed. Internal genitalia not dissected but can be distinguished through the integument as being of the dual 'mound' or 'funnel' type, i.e. with two clearly separated basal mounds. Genitalia of one paratype dissected (fig. 30). *Carapace* length paratype (BYM 52/575), 4.1 mm; paratype (BYM 52/561), 6.4 mm, this being the largest specimen of the species observed.

#### Natural History

The holotype was collected from a simple burrow in a sea cliff, overlooking the mouth of the Todd River. The cliff face was overhung by shrubs. High tide washed the cliff base. A flimsy cocoon of eggs was found in the burrow. It contained eleven subspherical eggs, all at an early developmental stage, with diameter of 2.0 mm.

The Cummins specimens occurred under mallee, two in moss-grown creek alluvium, two under mallee litter; the "Coomunga Springs" spider was found with other mygalomorphs under an isolated clump of bottlebrush in a grassy, farm paddock; the Streaky Bay spider was under casuarinas. The silk-lined burrows have the mouth formed into a silk collar, which may be retracted to close the burrow. A soil plug may be placed beneath the closed collar thus effectively sealing the nest. In the sealed burrow

of one paratype (BYM 52/561) was a cluster of fifty-five recently hatched spiderlings; these had no pigment and had carapace lengths of 1.1 or 1.2 mm.

*Adult Male* unknown.

#### Specimens examined and localities

S.A.: ♀, mouth of the Todd River north of Port Lincoln, Eyre Peninsula, (holotype); 2, Cummins, 8 miles east, (includes paratype, BYM 52/575); 1, Cummins Plains (paratype BYM 52/561); 1, "Coomunga Springs", west of Port Lincoln.

Immature males: 1, Cummins, 8 miles east; 1, Streaky Bay, east of; 1, Port Lincoln.

W.A.: 2 juveniles and one immature ♂ (?), Porongorups Range (near Bolganup dam), (collected by J. Springett by sieving litter and humus); 1 juvenile 3 miles north of Mammoth Cave, W.A.

The Western Australian specimens and other South Australian specimens all agree with the holotype in the presence of a definitive 'pseudorastellum', uniformly mottled abdomen, the distinctive annulations on the legs, absence of scopula on third and fourth tarsi and fewer spines on the legs, especially of the third and fourth. It is the combination of these features and the small size which distinguishes *occidentalis* from the other species.

#### Stanwellia inornata sp. nov.

##### Types

Holotype, ♀, Rose's Gap, Grampian Mountains, Victoria, collected by B. Y. Main, 28 November, 1965 (BYM 65/704), (Australian Museum No. K69299)

♂ Paratype (BYM 65/706), (Australian Museum No. K69300)

♀ Paratype (BYM 65/711), (National Museum No. K-25)

Data for paratypes as for holotype.

#### Description of Holotype

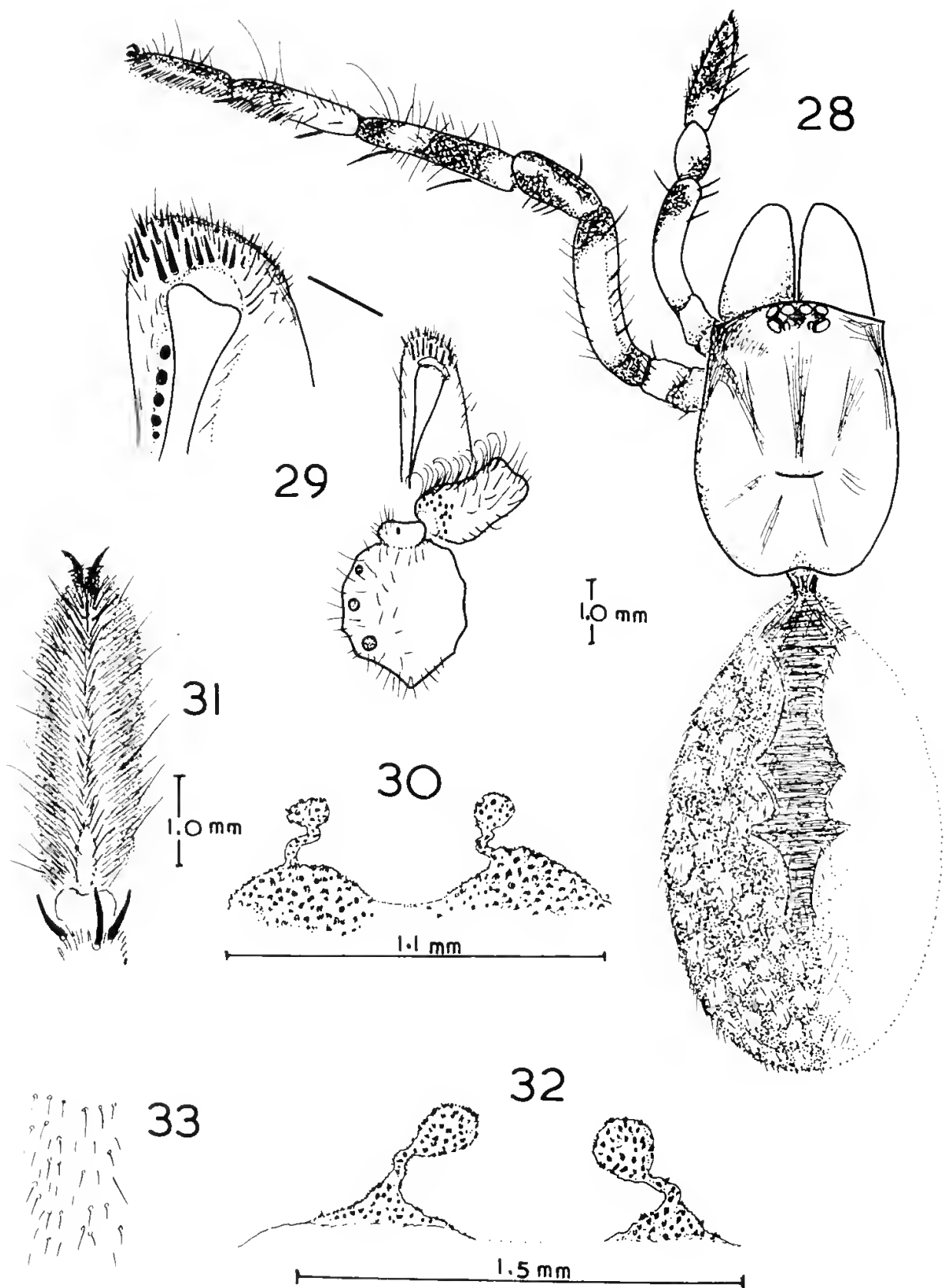
*Female*: *Carapace* length, 8.8 mm, width 7.3 mm. Colour, uniform dusky brown, in life no pattern visible on legs or abdomen, generally brown and hairy-looking with golden sheen. *Fovea* almost straight. Anterior width of eye group 1.8 mm. *Labium*, length 1.1 mm, width 1.7 mm, 2 cuspules, *sternum* length 4.9 mm, width 3.8 mm, sigilla oval. *Chelicerae* with 9 teeth on promargin of furrow, basal cluster on outer margin extending up to about fourth inner tooth. Palp tarsi each with single basal fine tapering spine. Legs, scopula present on all tarsi and metatarsi I and II, a few apical hairs on metatarsi III. Scopula of tarsi III and IV divided by band of median bristles (fig. 31). Tarsal claws with 4 to 8 teeth in each comb of bipectinate claws.

Leg formula: 4 1 2 3  
2.57 2.55 2.31 2.23

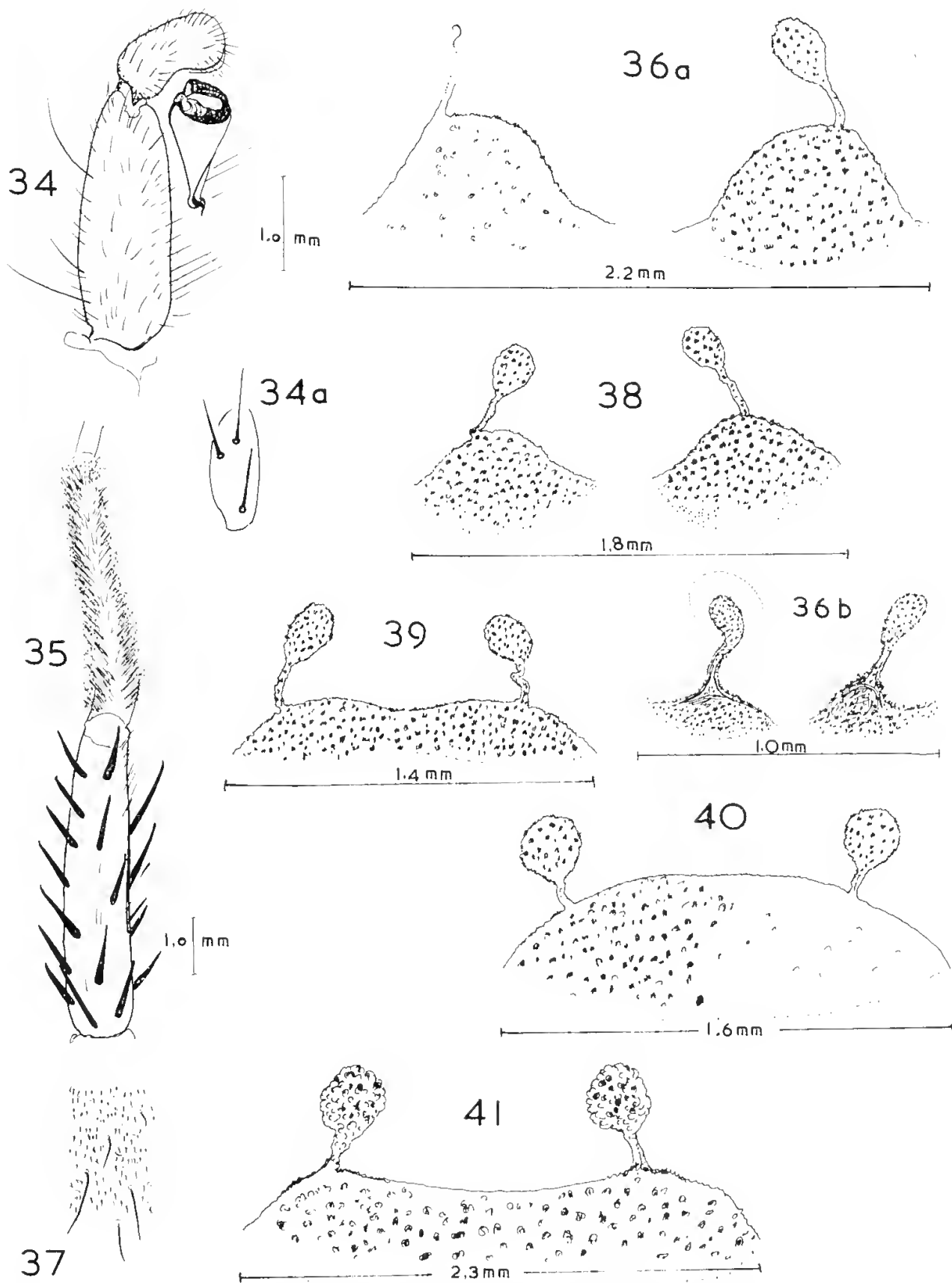
Tibial index I, 14.6, Tibial index IV, 14.7

*Spines*. Distribution of spines as follows: No dorsal spines or bristles on femurs. I, Metatarsus, 2-1-2 ventral; Tibia, 3 apical ventral spines and 3 ventral bristles, 3 prolatero-dorsal. II, Metatarsus, 2-2-2 ventral, 1 prolateral; Tibia,





Figures 28-33.—28-30, *S. occidentalis* Main. 28, dorsal view ♀ (Holotype); 29, chelicerae, labium and sternum. (Holotype); 30, ♀ internal genitalia (Paratype, BYM 52/561). 31-35, *S. inornata* Main. 31, left tarsus III, ventral; 32, ♀ internal genitalia (Paratype BYM 65/711); 33, abdominal pilosity (BYM 65/705).



Figures 34-41.—34-35, *S. inornata* (♂ paratype). 34, right palp retrolateral, 34a, tibia prolateral; 35, right tibia I ventral. 36-41, unidentified *Stanwellia* specimens. 36a b, ♀ internal genitalia, 36a (BYM 65/41), 36b (BYM 65/39); 37, abdominal pilosity (65/685); 38-41, ♀ internal genitalia, 38 (BYM 65/685); 39 (BYM 65/677); 40 (BYM 59/404); 41 (BYM 65/48).

3 spines and 3 ventral bristles. III, Metatarsus, 2-2-1 ventral; Tibia, 7 fine tapering ventral spines, 6 dorsal, 4 prolateral, 1 retrolatero-ventral; Patella, 1 dorsal; 4 stout prolateral; 2 retrolateral. IV, Metatarsus, 2-1-1-2 ventral, 2-1-2 dorsal, 1 prolatero-ventral; Tibia, 2 spines and 4 bristles ventral, 2 prolatero-dorsal.

Palp. Tarsus, 1 basal; Tibia, 2 apical ventral spines and 6 ventral bristles; 2 spines and 2 bristles prolateral.

*Paratype Female*: Carapace length 8.5 mm, width 6.5 mm.

*Labium* with 3 cusps. Internal genitalia consist of small basal, denticulate mounds connected by thin, bent tubes to globose vesicles (fig. 32).

*Paratype male*: Carapace length 7.0 mm, width 5.8 mm. Colour generally a uniform dusky brown, no pattern apparent on legs or abdomen in life. Carapace with dense marginal hairs. Generally hirsute, the hairs with golden sheen; abdomen with long fine bristles amongst the hairs. Palp as figured (fig 34); right tibia with three long fine prolateral bristles (fig 34a), left tibia with only two bristles. Tibia I with 7 ventral spines, 6 retrolatero-ventral, 6 prolatero-ventral (fig. 35).

Leg formula:

4	1	2	3
3.5	3.48	3.16	3.16

Tibial index I 12.36. Tibial index IV 13.25.

*S. inornata* differs from other described males of *Stanwellia* in having more attenuated palpal-stigma and relatively longer, thinner legs and lacks a distinct mottled colour pattern.

#### *Specimens examined*

Three types as above and two other females [of which one specimen (BYM 65/705) has four labial cusps; and abdominal pilosity as figured (fig. 33)], all from Rose's Gap, Grampian Mts., Victoria.

#### *Distribution of S. inornata and S. grisea in the Grampian Mountains*

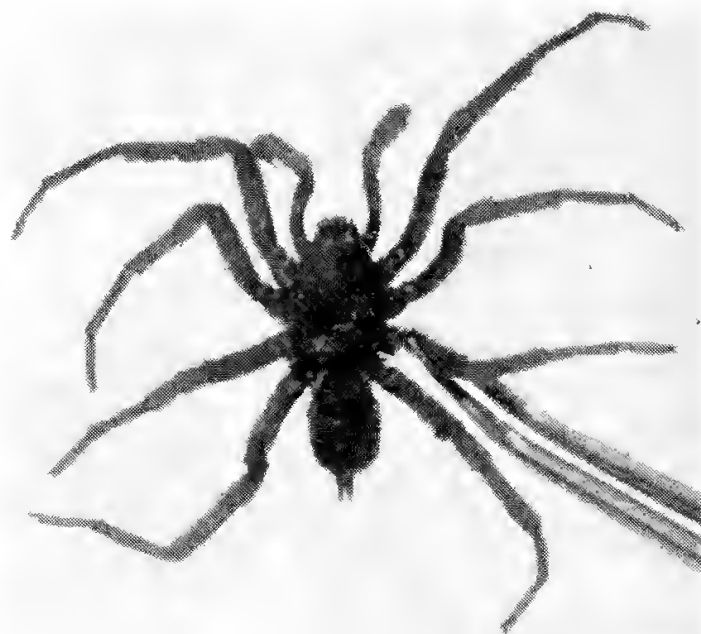
The occurrence of what appear to be two species in the Grampian Mountains is notable. *S. grisea* occurs in the eastern gullies of the mountains. *S. inornata* has been found only along a creek in Rose's Gap (but probably extends farther). This latter area has a sandy soil type and a heath vegetation understorey which is distinct from the plant associations of the eastern regions. At this same locality *Aganippe* was also collected. This ctenizid genus has not been observed in the wetter, eastern localities of the mountain range.

#### *Unidentified Stanwellia specimens examined*

The following specimens were all collected by the author except where otherwise stated.

2 ♀♀ and 2 juveniles, Lakes Entrance, V. 1 ♀ Harris Creek, V. 3 ♀♀ and 1 juvenile, 30 miles from Orbost on Bonang Highway. The internal genitalia of two females (BYM 65/41 and 65/39 with two basal denticulate mounds as in figs. 36a and b. 1 ♀ Otway Ranges, V. This specimen (BYM 65/685) in life glabrous and a uniform, light tan colour, lacking dark smudges

or annulations on the legs. Abdomen with short, thornlike bristles and long tapering bristles (fig. 37). Internal genitalia with large basal mounds (fig. 38). 5 ♀♀ Lake Mountain, V. One female (BYM 65/677) with internal genitalia as in fig. 39. 1 ♀ Mount Beauty, V. 9 ♀♀ Donna Buang, V; internal genitalia (BYM 59/404) as in fig. 40. 1 ♀, Mt. Ben Lomond (4000') Tasmania (collected by V. V. Hickman); 1 ♀ and 1 immature specimen Table Cape, Tasmania (collected by V. V. Hickman). 1 ♀ about 1 mile N. Piccadilly Circus, Brindabella Ranges, A.C.T. (internal genitalia as illustrated in fig. 41, BYM 65/48); 1 ♀ Uriarra State Forest, A.C.T. (BYM 65/44), internal genitalia similar to BYM 65/48; 1 ♀ Black Mountain, A.C.T. collected by A. R. Main; 1 ♀ Brindabella Ranges, A.C.T. collected by A. R. Main; 2 ♂♂ Coree Flats, Brindabella Ranges, A.C.T. collected by R. Pengelly. All these A.C.T. specimens were at first thought to be *S. hoggi*. Some of them were collected in association with *Dyarcyops fuscipes* (Rainbow), which is a common ctenizid of the Sydney and Blue Mountains' regions. However, when the Brindabella specimens were observed to have a distinctive type of internal genitalia (fig. 41), similar only to high, mountain-locality specimens from Victoria (Lake Mountain and Donna Buang, (figs. 39, 40) the possibility that they were of an



C.Y.M. 65/23

Figure 42.—*Stanwellia grisea* (Hogg) Dorsal view of male specimen. Note that there is no spur on tibia of first leg (BYM 65/23). (Natural size x 1.7)



Figure 43.—*Stanwellia nebulosa* (Rainbow and Pulleine)  
Dorsal view of female specimen (BYM 55/727) (Natural  
size x 1.8)

undescribed species, perhaps with relictual populations scattered along mountain tops of the southern part of the Dividing Ranges had to be considered.

#### Taxonomic Value of Female Internal Genitalia

Schiapelli and Pikelin (1962) and Forster and Wilton (1968) have used the internal female genitalia to distinguish genera and species of Mygalomorphae. The present author while regarding this structure as a useful guide, especially to *genera*, has noted variability of outline contours amongst specimens of the one species, as in *S. grisea* and *S. pexa*. Also the similarity of basic form between certain species is such that, alone, this character would not distinguish the species. Specimens of *S. grisea*, *pexa*, *occidentalis*, *inornata* and several unnamed populations all have the basic form of two mound-like 'funnels' each connected to a blind vesicle. The vesicle may be ovoid or spherical, the connecting duct straight or bent and the 'funnels' large and rounded or suppressed. It is possible that the degree of 'inflation' of the vesicles and basal mounds may

be related to sexual activity of the animal. This requires investigation by collection and dissection of animals from the one locality at different times of the year. The degree of distension of the genitalia parts does not appear to be related to gross size of the animal but may possibly be affected by partial desiccation. Unnamed high-mountain forms of *Stanwellia* have a single, broad basal mound giving off two ducts which connect to the vesicles (figs. 39, 40, 41). Probably this basal mound represents a fusion of two single 'funnels'. It is interesting that Forster and Wilton (1968) figured two basic forms of genitalia structure for the New Zealand genus *Aparua* which are similar to the two basic forms observed in the related *Stanwellia*. The structure of the internal genitalia of *S. hoggi* has not been observed.

#### Discussion

##### *Biology and Life History*

From collection dates of males and the seasonal occurrence of eggs in the burrow it is deduced that *Stanwellia* males wander and mate in the autumn and that eggs are laid in late spring. Presumably, young disperse in the autumn and early winter. It is possible that this biological association with an autumn/winter wet season has been the chief factor restricting the range of the genus northward into the summer rainfall/winter drought regions of Australia. The genus appears to be tied to autumn/winter rain for breeding and dispersal and at the same time requires continual year-round humidity (except possibly *S. nebulosa* which is the only species occurring in a region of severe summer-drought). *S. occidentalis* in Eyre Peninsula, and in the south-west localities of Western Australia, occurs in situations where the micro-habitat effectively simulates a continuously 'humid' environment.

##### *Geographic Distribution*

The distribution of *Stanwellia* is of interest for several reasons:

(i) It occurs in extreme types of habitats ranging from mountainous situations above the snow line (for example in the Brindabella Range, A.C.T., Lake Mountain and Donna Buang, Victoria and other localities in Victoria), on islands of the Bass Strait, to semi-desert habitats in the limestone country of western Victoria, eastern S.A. and to coastal cliffs just above the sea in Eyre Peninsula. Associated with these great habitat differences are behavioural adaptations, notably in the structure of burrows.

(ii) Occurrence of the genus in the south western corner of W.A. probably represents an isolated relict of an earlier continuity along the coastal strip from S.A. This particular westward extension in range of an essentially south-eastern Australian genus, appears to parallel the former range of some mammals, such as the Tasmanian devil and koala, fossils of which have been found in limestone caves of south-western W.A. Apparently, because of the smaller size and minimal area requirements of the spider it has been able to persist in restricted

localities after the mammals became extinct in the region. This disjunct distribution parallels in part that of the Mygalomorph family Migidae. An undetermined genus of the subfamily Calathotarsinae occurs in the Stirling Ranges and Porongorups in Western Australia and the Grampians and mountains north of Melbourne in Victoria (Main unpublished data).

(iii) The morphological similarity of *Stanwellia* and the New Zealand genus *Aparua* Todd indicates a close relationship between the two. Such a fragmented distribution possibly implies great antiquity and parallels in part the similar fragmented distribution of other Mygalomorphae common to Australia and New Zealand notably *Hexathele* (sub-family Hexathelinae of Dipluridae) which is found right down eastern Australia, westward into S.A. and also in Tasmania; *Migas* (family Migidae) occurs in New Zealand and Tasmania but not mainland Australia; *Dyarcyops* (family Ctenizidae) ranges from New Guinea (two species at present included in *Arbanitis* (Rainbow 1920)), through eastern mountainous Australia to Tasmania and westward to S.A. It also occurs in New Zealand where its species are included in *Cantuaria* by Forster (1967) and in Forster and Wilton (1968).

(iv) The southern and essentially south-eastern distribution of *Stanwellia* (it has not been found north of Sydney and does not extend into Queensland) and its close relationship to the New Zealand genus *Aparua*, suggests an ancient origin. The possibility of affinities with South American and/or South African and Mascarene genera might profitably be looked for.

#### Deposition of Specimens

Types of earlier described species, specimens cited by previous authors, and various formerly unnamed specimens sighted by the present author are located in museums as listed above under the species. All new types (see species descriptions above) are being deposited in the Australian Museum, Sydney, the National Museum, Melbourne and the South Australian Museum. The following specimens which have been cited in the text have been deposited in the Australian Museum; corresponding Museum register numbers are given in brackets after the author's numbers.

*Stanwellia grisea* (Hogg): BYM 65/11 (K69308), BYM 65/16 (K69306), BYM 65/27 (K69307), BYM 65/693 (K69305).

*S. hoggi* (Rainb.): ♂ specimen collected by R. Mascord (KA1).

*S. nebulosa* (Rainbow and Pulleine): BYM 55/727 (K69303), BYM 59/425 (K69304). *S. pexa* (Hickman): BYM 54/65 (K69309), BYM 54/66 (K69310), BYM 70/38 (a ♀ specimen collected by V. V. Hickman from Queen's Domain, Hobart) (K69312), BYM 70/36 (collected by V. V. Hickman from west coast Tasmania) (K69311). Unidentified *Stanwellia* specimens: BYM 59/404 (K69313), BYM 65/39 (K69314), BYM 65/41 (K69317), BYM 65/48 (K69315), BYM 65/677 (K69316), BYM 65/685 (K69318). All other specimens in the author's collection

are lodged at the Zoology Department, University of Western Australia.

#### Acknowledgements

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# 13.—Mulga (North) Chondritic Meteorite Shower, Western Australia

by W. H. Cleverly\*

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## Abstract

Further recoveries in 1970 and 1971 of the stony meteorites Mulga (south), Billygoat Donga, and Mulga (north) demonstrate the partial overprintings of their strewnfields, though the sequence of arrival is uncertain. A total of 781 fusion-crusted stones or fragments of Mulga (north) of aggregate weight 19.5 kg have been recovered from an elliptical strewnfield of dimensions 6.1 x 1.2 kilometres. Detailed field records of the circumstances of occurrence and sites were maintained.

The degrees of entirety of the stones and stages of development of fusion crusts have been defined and are described for individual stones by a system of code letters; textures and minor features of the crusts are briefly noted. The stones stably oriented in flight have been nominated and the criteria used are stated. The sphericities of individual stones, their weights, and where possible the weights when restored to a fully primary crusted condition have been determined.

The degree of fragmentation does not appear to have been as great as for showers such as Holbrook. A complex series of aerial fragmentation events is indicated for Mulga (north) by the frequent occurrence of fusion crusts of various developmental stages on different facets of the one stone; re-assembled stones provide further evidence of the step-wise nature of the breakdown; the spalling of thin flakes from the surfaces also contributed. The applicability of the Gaudin relation to the size distribution has been examined, and an attempt made to isolate the products of the initial fragmentation for similar study.

The field distribution has been treated only qualitatively but a detailed tabulation of the surface features, weights, and morphology together with the co-ordinates of the sites of find of all pieces has been prepared as the basis for study of the field distribution and of the factors which could influence it.

## Introduction

Details of the stony meteorites Billygoat Donga, Mulga (south), and Mulga (north), and of their recoveries during the period 1962-66 from a small area centred 95 km N.N.E. of Haig, Western Australia, are available in literature, but a brief summary is desirable before detailing the recent recoveries. In 1962, T. and P. Dimer found three small meteoritic stones close together about 11 km north of Billygoat (or Mulga) Donga, which is located ca. 30° 08'S., 126° 22'E. They lost two of the stones and the remaining one became known as Billygoat Donga (I). In 1963, the A. J. Carlisles Snr and Jnr. noted a shallow depression in the ground to the north of Billygoat Donga, and because it differed in some way from other natural features of the area, they suspected a meteorite crater, searched and found within it a 16 g

fragment of stony meteorite. No petrographical examination of this stone was possible, but it was recorded as Billygoat Donga II. The stone was returned to the finders and was subsequently lost.

Late in 1963 the writer sought unsuccessfully the crater described by the Carlisles, but found instead three fitting fragments of stony meteorite which were initially recorded as Billygoat Donga III. In the following year he found five more fragments of the same type, and in extending the area of search found a concentration of 59 stones of distinctly different morphology. Subsequent petrographical examination confirmed the distinction, though both are olivine-bronzite chondrites with fayalite index 18, and simultaneously demonstrated that they were unrelated to Billygoat Donga I which is an olivine-hypersthene chondrite with fayalite index 25. Billygoat Donga III was re-named Mulga (south), and the concentration of 59 stones together with a further 12 found in 1966 was named Mulga (north). Billygoat Donga thus remained represented only by the small stone found by T. and P. Dimer (McCall and de Laeter 1965; Cleverly 1965; McCall 1968; McCall and Cleverly 1968).

The extended distribution of 13 more stones of Mulga (north) recovered during a brief visit in 1967 (bringing the total to 84) made it increasingly likely that the known material was but a fraction of a considerable shower. A field trip in December 1970 had as one of its principal objectives the collecting of Mulga (north) and the delineation of its field of occurrence. It was expected that search would be facilitated by minimal grass cover in the summer season, though climatic conditions might be extreme; both expectations were fully realised. In nine days, three searchers recovered 325 pieces of meteorite from within an elongate area of complex shape and of dimensions exceeding 4 x 1 kilometres. From their distinctive morphologies 321 pieces were recognised as Mulga (north) and 3 as Mulga (south). A single piece resembled the Billygoat Donga (I) stone which had been found about six kilometres further north eight years previously. In response to a request for determination of the fayalite index of the olivine, Dr. Brian Mason stated (pers.comm)—“a typical hypersthene chondrite with olivine composition Fa 25 . . . indistinguishable from Billygoat Donga; even the degree of weathering is the same”. A triple overprinting of the strewnfields of these three meteorites had thus been demonstrated.

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When a detailed plot of these occurrences was prepared, it was realised that the gaps and apparent anomalies in the distribution of Mulga (north) might be only deficiencies in the data. A further field visit was therefore made in December, 1971 to concentrate search on gaps and critical areas. As the result of a dry year without seasonal growth of grass the ground



Figure 1.—View westward in the middle section of the strewnfield of Mulga (north) meteorite, about 95 km N.N.E. of Haig, Western Australia. Trees in left middle distance are in Three Mile Donga (see Fig. 2). Well-used vehicle track at right connects the main line of survey stations extending roughly along the axis of the strewnfield. Photographed in December, 1971.

surface was ideal for search (Fig. 1). The same three persons found 391 pieces of meteorite in 9½ days, extending the strewnfield to a narrow ellipse of dimensions 6.1 x 1.2 km and of area 5.4 square kilometres. The recoveries included 13 pieces of Mulga (south), a fragment of Billygoat Donga fitting the stone found in 1970, and a small stone since named Mulga West. The position may now be summarised whilst referring to Figure 2.

1. Mulga (north) is known by 781 pieces of total weight 19.5 kg and its strewnfield can be reasonably defined except at the ends. The direction of flight was eastward. Very small individuals comparable with the Pultusk and Holbrook "peas" may exist at the western end but extreme climatic conditions mitigated against their observation and recovery. A few individuals weigh less than one gram, the lightest 0.37 gram. It is likely that a few large stones are still in situ within and beyond the eastern end of the known strewnfield, and that some of them might be completely embedded. Limitations of time precluded a detailed walking search, and the heaviest stone (the easternmost), was recovered during a reconnaissance type search by vehicle on widely spaced grid lines; only two fifths of its vertical dimension was above ground surface.

2. The Mulga (south) meteorite is known by 24 pieces of which all except five have the typical morphology of the earlier known material, i.e. are fragments with discontinuous areas of dark, very thin, fusion crust. The other five have additionally some remnants of an older,

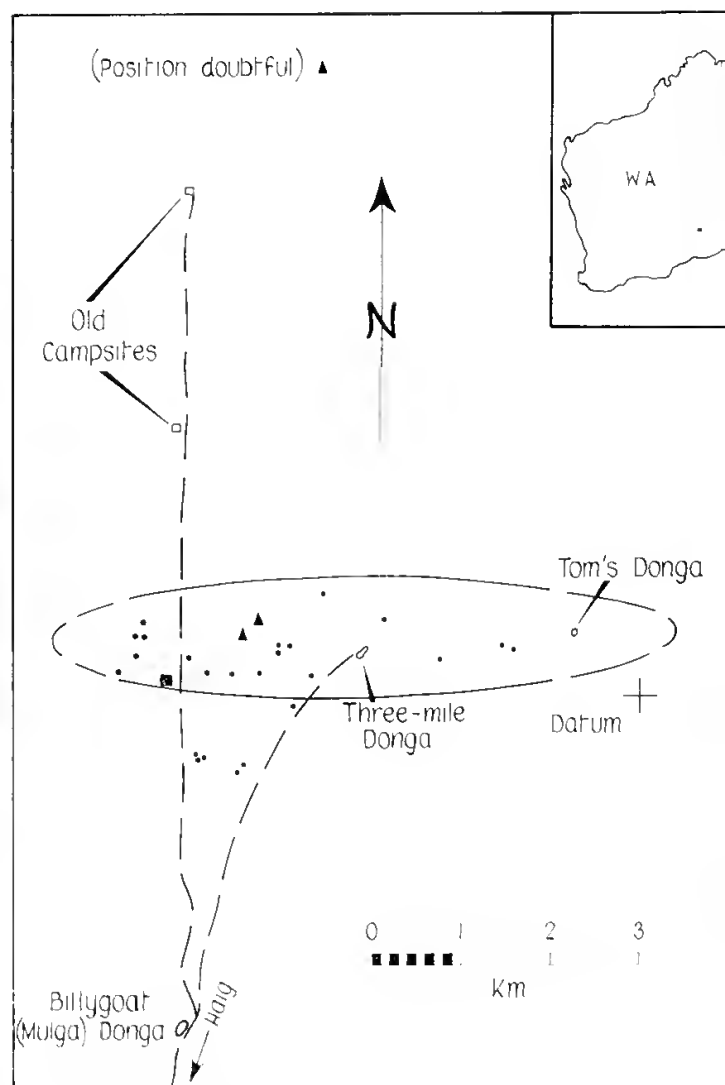


Figure 2.—Sketch map showing location of the approximately elliptical strewnfield of Mulga (north) stony meteorite in relation to Billygoat Donga, Western Australia. Sites of find of the Mulga (south) meteorite (dots), the Billygoat Donga meteorite (triangles), and the Mulga West meteorite (square symbol) illustrate the overprinting of their strewnfields. Coordinates of individual sites of find are measured relative to the datum indicated.

smoothly curved, primary type surface. The total known weight is 894 grams. The extent of the strewnfield and direction of flight are not evident. The rather curious distribution shown in Fig. 2 is the result of detailed search within the strewnfield of Mulga (north) coupled with only the most casual search or none at all in most parts of the surrounding area.

3. The Billygoat Donga meteorite is known by three pieces of total weight 633 grams. The site of find of the original stone is known only very approximately. The other two pieces, which were found 230 m apart during different field visits, fit to form an almost complete, fusion-crust individual of nearly 500 grams. The form of the strewnfield is unknown. Because the original stone was reported to be one of three small individuals found close together, and the later finds constitute a much heavier and apparently isolated individual, the general direction of flight might have been southerly.

4. The Mulga West meteorite is known by a single, small, almost brick-shaped stone of weight 169.2 g found near the western end of the Mulga (north) strewnfield (Fig. 2).

*Note added Aug 10, 1972.* Dr. G. J. H. McCall advises (pers. comm.) that Mulga West is of rare type and thus unrelated to the other three common chondrites. Four meteorites are therefore represented within the Mulga (north) strewnfield.

Mulga (north) is less weathered and is a later arrival on earth than Mulga (south) (McCall and Cleverly 1968). Billygoat Donga is also somewhat weathered but the few pieces known do not appear to be as deteriorated as some of the more recently recovered stones of Mulga (north). It might be the most recent arrival or intermediate in age. Comparisons are made difficult because Billygoat Donga is of a different petrological type to the other two. A comparison of the specific gravities of stones of comparable weights with the probable values for fresh meteorites (Table 1) is inconclusive.

All three meteorites are "finds" of common chondrites and their material value is relatively small, but all except 1 of the 809 pieces were found by persons of scientific training, and the maintenance of unusually complete records of the circumstances of occurrence and locations has been possible. These data are especially valuable for Mulga (north) and should provide a partial answer to the plea of Frost (1969) for such details.

It is surprising that after about 70 man-days have been spent in the area, the crater which was seen by the Carlises in 1962 and which initially drew attention to the area, remains unrecognised. The Carlises, with the accumulated knowledge of three generations and over half a century of familiarity with the Nullarbor Plain are probably the best qualified of anybody to decide that a feature is unusual. Their unparalleled record as finders of meteorites (McCall and Cleverly 1970 Table 1) attests to the acute powers of observation they have

needed to develop in this generally inhospitable region. Moreover, they have since, in 1966, recognised the impact crater of the Pannikin meteorite and collected small chips of stony meteorite from within it (McCall and Cleverly 1968). With the advantage of hindsight, the Billygoat Donga II stone from the crater resembled Mulga (north), but it is difficult to believe that a crater-like feature of the order of 10 m diameter could have escaped notice within the known strewnfield.

A by-product of the search was the recovery of 102 australites (tektites), or about 19/square kilometre. Their total weight is 127 grams. Nearly all are fragments and several are clearly artefacts; all five of those selected for expert examination were confirmed as artefacts by C. E. Dortch (pers. comm.). Such artefacts were evidently discarded by itinerants or date from times of more humid climate because present sources of water are ephemeral. An occasional clay-floored donga\* such as Billygoat Donga could hold shallow water only very briefly; no rock holes of significant water capacity are known in the area.

### Mulga (north) meteorite

Reference will be made in the balance of this paper to Table 2 which, as reproduced, contains only those stones specifically referred to in the text and a few others illustrating types. It is neither practicable nor necessary to reproduce the full table of 781 items which is of interest principally to the specialist student of the mathematics of fragmentation and distribution. A copy of the full table is available on application to the Director, Western Australian Museum, Perth, Western Australia.

\* The term donga is used on the Nullarbor Plain for shallow, sometimes extensive, sink features of the limestone surface. Many dongas contain growths of trees (Fig. 1), and being campsites favoured by itinerants, are often named by them, though few such names have official recognition.

Table 1.

*Comparison between specific gravities of meteorites as found and values of unweathered types*

Meteorite and Type	Specific gravities of pieces in weight range 90-145 grams	Weighted mean of preceding column	Range of specific gravity for unweathered meteorites of same type (Mason 1962)	Range of mean weathering effect (Col. 4 minus Col. 3) and maximum individual effect
Mulga (south) CBr	3.333, 3.364	3.35	3.6-3.8	0.25 to 0.45 0.47
Billygoat Donga CHy	3.380, 3.434	3.41	3.5-3.6	0.09 to 0.19 0.22
Mulga (north) CBr	3.590, 3.600, 3.608, 3.605, 3.602, 3.612, 3.604, 3.585	3.60	3.6-3.8	0.00 to 0.20 0.21

Table 2.

*Field numbers, classification, weights, orientation, sphericity, and coordinates of sites of find for some stones of Mulga (north) meteorite*

Field number	Classification	Weight g	Weight as CP g	Orientation	Sphericity	Westing km	Northing km
3	FPU	77.4	....	....	0.70	3.76	0.61
27	CP	73.6	73.6	X	0.75	3.18	0.72
33	CPT	111.3	129.3	X	0.51	3.57	0.58
65	CPS	27.3	....	....	0.69	3.84	0.85
111	DPTU	336.4	340.1	X	0.78	2.75	0.91
118	CPS	87.3	....	X	0.61	3.04	0.45
128	CPS	169.1	....	X	0.69	2.15	0.49
135	CPT	22.9	....	....	0.60	3.21	0.39
139	FPUT	23.8	....	....	0.63	2.27	0.60
140	FPTU	4.7	....	....	0.78	2.28	0.61
141	CTP	4.2	....	....	0.53	2.28	0.60
146	CPT	22.1	....	....	0.42	3.93	0.78
149	FPTSU	99.1	....	....	0.51	2.89	0.44
150	DPSTU	58.9	....	....	0.71	2.91	0.43
155	FPUT	151.3	....	....	0.63	4.10	0.98
159	CPT	0.5	....	....	0.48	2.20	0.84
164	CP	205.9	205.9	X	0.75	2.13	0.64
167	CP	188.1	188.1	X	0.69	1.88	0.77
174	CPT	60.0	61.5	....	0.69	3.51	0.37
176	FSUTP	56.4	....	....	0.53	3.52	0.40
199	FPSU	44.9	....	....	0.62	3.80	0.92
208	CTSP	188.3	....	....	0.73	1.55	0.56
209	CTSP	245.7	....	....	0.83	1.42	0.62
218	CPST	14.5	16.3	X	0.68	4.22	0.71
245	CPT	4.8	4.8	X	0.57	4.81	0.71
260	CPS	7.2	7.2	X	0.71	4.98	0.58
309	CPST	5.0	5.0	X	0.69	5.06	0.65
321	CP	0.4	0.4	....	0.75	5.11	0.60
390	FPTU	4.8	....	....	0.72	5.47	0.52
448	DPU	0.4	0.4	....	0.60	5.64	0.56
469	CPT	5.5	....	....	0.51	4.63	0.29
473	DPTU	2.6	3.0	....	0.88	4.62	0.52
499	FPU	64.7	....	....	0.66	3.59	0.71
533	CPF	347.9	371.0	....	0.66	2.15	0.35
542	CP	533.4	533.4	....	0.77	2.06	0.73
638	CPT	8.7	9.3	X	0.61	5.25	0.88
677	CPT	64.7	64.9	X	0.66	3.79	0.19
758	CP	4.9	4.9	X	0.67	5.19	0.75
807	DPU	2095	2110	...	0.68	0.05	0.60
822	CPT	2.5	2.5	...	0.63	4.94	0.47

#### *Field occurrence*

Stones are identified in Table 2 by their field numbers (column 1). Most of the numbers missing from the full table are accountable either to other meteorites or to spurious material. In the field, fragments showing some degree of weathering and separated by distances of up to one or two tens of centimetres were regarded as products of disintegration and were recorded as a single stone. Likewise, when two or three fitting stones not showing advanced weathering were found up to a few metres apart, they were accepted as impact fragments and recorded as one stone; the situation was especially clear when such a group was found relatively isolated from other stones. As a result of this recording procedure, both the number of stones and the amount of uncrusted meteorite surface attributable to impact or weathering have been minimised.

More than 90% of the stones lay on the surface of the ground or were embedded only to the extent of inequalities of the contacting surfaces. The remainder were embedded from one quarter to (rarely) as much as three quarters of their vertical dimension, and of those so embedded many are judged to have been oriented stones in flight position. The general shallowness of the embedding and some of the other features—such as the infrequent occurrence of regmaglypts—result from the generally small size of the stones.

The survey of the strewnfield was made by prismatic compass and pacing, a method adopted initially of necessity because the writer was unaccompanied when the first 59 stones were found. Use of this procedure continued during later field trips because atmospheric refraction effects restrict so severely the times of the day when instruments can be used, and because the

opportunities for field work in this area are very limited. The two original survey stations were supplemented during later searches to form a chain of 16 stations with a branch line of one or two stations to each side of the main line where required. From these stations all sites were paced in. The speedometer reading for a vehicle traverse along the main line of stations, after adjustment for known error, differed from the plotted length by 3%. A large overall error is therefore unlikely, and because the pacing was done by the same person on all five occasions, internal distances should be in proportion and any errors of the same order.

Co-ordinates of individual sites of find (last two columns of Table 2) are westings and northings in kilometres from an arbitrary datum located 0.05 km east of the easternmost site (the heaviest stone) and 0.05 km south of the southernmost site (see Fig. 2). Because the axis of the strewnfield is approximately west-east and the direction of flight was eastward, the westings are in the form which has become conventional for the mathematical description of lateral distribution, while the northings are an expression of the distribution transverse to the axis. Co-ordinates have been rounded to the second decimal place (the nearest 10 m) and as a result of this, a few pairs of sites have identical co-ordinates.

It is believed that the stones were found close to their original points of fall. Ground slopes are generally very low and, to judge by the insignificant drift of weathering fragments from their parent stones, the amount of movement of the stones is likely to have been very small. The aboriginal inhabitants appear to have made no use of the stones.

#### *Features of individual stones*

Stones generally have the angular, faceted yet smooth form which results from fragmentation followed by development of fusion crust, but many stones also have surfaces free of crust or thinly veiled by crust.

The degree of entirety of the stones, the stage of development of the fusion crust(s), and the relative areal abundances of the crust types are indicated by a system of code letters in column 2 of Table 2.

The degree of entirety is expressed by either C, D or F. C denotes completely fusion-cruste stones, irrespective of the degree of development of the crust(s). D indicates stones with one, or occasionally more than one surface lacking crust, and having a profile such that a probable reconstruction to fully crusted form can be made. This type of stone is generally much more than 50% of the mass of the original but lacks a "cap piece" or "edge piece". F indicates fragments with at least one surface free of crust and whose profile does not allow a confident reconstruction of the shape; some of these are the type of fragment lacking from category D stones.

The degrees of development of crust are indicated by P, S, and T. P indicates the primary crust of smoothly curved surfaces from which

all except centimetre-sized inequalities have been smoothed out. It is close-textured or knobby, except for localised developments of scoriaceous or striated texture, particularly on stones which were stably oriented in flight (for textural terms see Krinov 1960). S denotes surfaces of the second kind ranging from finely rippled surfaces with crusts which barely veil the roughness of the fracture to coarsely wavy surfaces which are not always clearly distinguishable from primary crust, though the distinction is easily made when the two types occur on different facets of the one stone. These crusts do not commonly develop knobby texture, presumably because some minimal degree of development is necessary before the superior refractoriness of disseminated metallic grains can be expressed in that way. T denotes tertiary crusts covering the developmental range:—"smoking" of the surface, discontinuous films with mineral visible through gaps or through the crust, films through which mineral is only occasionally seen, complete crust which fails to hide the roughness of the surface and has an almost hackly appearance. Beyond this stage is the finely rippled crust of the secondary type. The nomenclature is similar to that of Foote (1912) for the Holbrook shower except that the hackly type is here placed in the tertiary category.

In very numerous cases the creep of crust over the edge of a later fracture surface indicates that a tertiary crust should be sought and that, even if such a crust is not detected, the surface must have been produced by acrial fragmentation. The creep of fusion crust is sometimes observed in the direction away from the surface of lesser crust development, e.g. from tertiary over primary surface on stone No. 99. This results from the adoption of an appropriately oriented flight position following the later fragmentation.

The letters P, S and T may be applied to different facets of the one stone representing surfaces produced by successively later fragmentation events or surfaces developed simultaneously on facets of an oriented stone enjoying different degrees of protection during atmospheric flight.

The system is admittedly subjective but a degree of sureness is developed by familiarity with the material. During second and subsequent re-examinations, most of the surfaces initially classified as doubtful could be classified with confidence. It is important to appreciate that even if the surface types were classified perfectly, there would be no implication that the surfaces of a given (say, secondary) type had developed following the same fragmentation event; rather, they are surfaces which have been exposed to similar sets of conditions possibly as the result of quite a number of different events.

U indicates uncrusted surfaces. By definition this letter cannot occur in combination with C and must occur with D or F. It might therefore appear unnecessary but it is required for the

following purpose. During a final review of the material the letters P, S, T and U were arranged in sequence of decreasing surface area. Each of the three types C, DU and FU can occur in seven combinations with crust types, e.g. CP, CS, CT, CPS, CPT, CST, CPST, but with the permutations arising from surface abundances the number of possible expressions is considerably increased. About 40 different expressions have been used.

Regmaglypts, usually shallow and of small size (1-2 cm) are sparsely present on only about 3% of the pieces, usually stones of weights exceeding 100 g or fragments which have clearly been derived from the larger stones.

Most stones show surface cracking ranging from single cracks to a complete breadcrust pattern initiated during the cooling of the surface in the later stages of atmospheric flight. A gaping breadcrust pattern occurs seldom, usually on the weathered and swollen underpart of a stone which has been embedded in the ground.

Because shape factors almost certainly affect the distribution, it is desirable that they be quantified, but such factors are difficult to assess. Stones which are stably oriented in flight can be expected to fly more truly and further than those which tumble and to be less affected by transverse winds. Much the same is probably true of stones whose shape approaches the

equidimensional compared with those of comparable weights which are tabular or otherwise inequidimensional.

A stable flight orientation (shown by X in column 5 of Table 2) is indicated by the presence of one or more of the following criteria:—

1. Roughly conical, pyramidal or wedged shapes embedded with point or edge down. Though the views illustrated in Fig. 3 have considerable similarity, they represent a wide variety of three-dimensional shapes. No. 111 (Fig. 3A) is representative of the conical and pyramidal stones; No. 128 (Fig. 3D) is a split pyramid which has developed secondary crust on the broken surface; No. 33 (Fig. 3E) is a roughly tabular stone which, despite losses and development of tertiary crusts, appears also to have been oriented in flight; No. 167 (Fig. 3F) is typical of a variety of stones with lozenge-shaped sections; it is roughly triangular with point down in the third (unillustrated) dimension; others with this type of section include more elongate and hence prismatic stones, which evidently had a leading edge in flight (e.g. No. 118). This criterion was not accepted as sufficient in itself because exceptions almost certainly occur. For example, the relatively thin, triangular No. 499 was embedded with the sharpest angle of the triangle downward, but such is an unnatural orientation for a stone having so much surface. No. 164 is oval in plan view, lozenge-shaped in section, and embedded in the

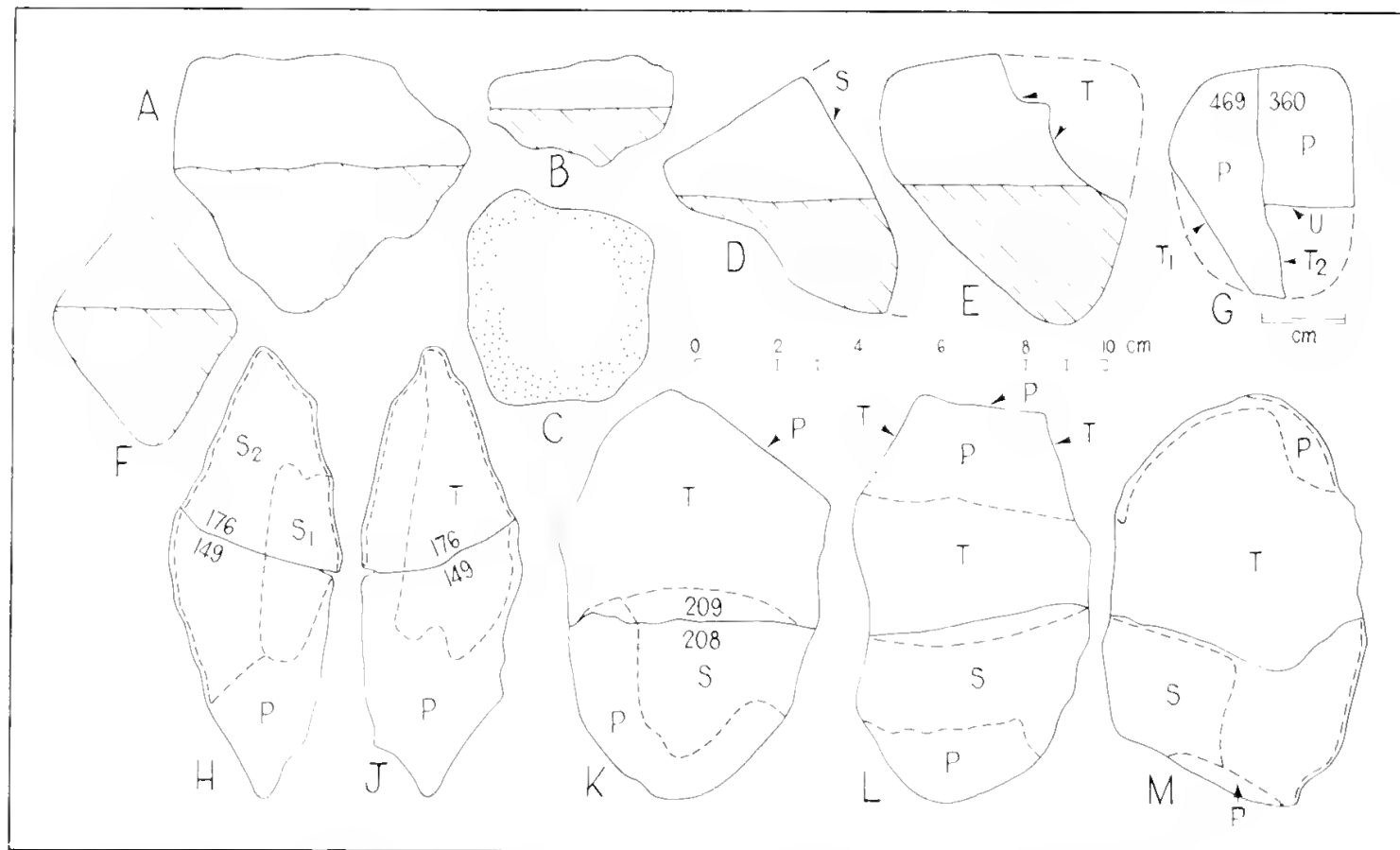


Figure 3.—Sketches of Mulga (north) meteoritic stones. A.—Profile of No. 111 showing soil line, embedded portion shaded. B.—As for A, No. 677. C.—Base of No. 677 showing encroachment of scoriaceous crust from the sides. D.—As for A, No. 128. E.—As for A, No. 33. F.—As for A, No. 167. G.—Composite stone 390/469, restored parts indicated by broken lines, surface types lettered as in text. H. and J.—Two views of composite stone 149/176 showing surface types. K. to M.—Three views of composite stone 208/209, which is roughly triangular in mid-section, showing surface types. The scale applies to all except G, for which a one-centimetre bar is shown.



manner of Fig. 3F, but the best-developed regmaglypts are on the surface found uppermost; it was probably oriented in flight but not in the position as found.

2. Regmaglypts of appropriate distribution, elongation, or alignment. The almost cuboidal No. 542 is shown to have been oriented by the regmaglypts and the distribution of scoriaceous crust rather than by its being embedded "edge on".

3. Textural types characteristic of frontal, lateral, and rear surfaces with appropriate distribution (Krinov 1960). In particular, small areas of scoriaceous crust to one side of surface irregularities or as a rim encroaching on one facet of a stone are common. Thus the flatly pyramidal stone No. 677 has regmaglypts on the front and a scoriaceous zone 5-10 mm wide rimming the flat base (Fig. 3 B, C). Examples of more sharply defined scoriaceous borders are on the bases of the flatly conical No. 758 and the almost tabular No. 638. It is necessary to distinguish this creep of crust from the much more general case when the stone was tumbling in flight. The regular width, and hence the apparently sharp edge of the overflowed crust on oriented stones is usually diagnostic. The striated texture (thin streams of melt glass) is occasionally detectable as a radial pattern on the apices of conical stones or over their lateral edges. Spattered droplets on the lee side of high points, as in the case of scoriaceous crust, occasionally provide additional evidence.

4. The combination of a primary crust with one of lesser development on a significant facet such as the base of a cone. Because there are other possible interpretations, such stones were not accepted as oriented without confirmatory evidence.

From a consideration of the above criteria 116 stones have been nominated as oriented during at least some part of their atmospheric flight. On a further 27 stones the evidence was less convincing. The oriented stones comprise at least three classes; firstly, those of category CP; secondly, those whose orientation during the earlier stage of flight preceding a secondary fragmentation is indicated by regular but incomplete rims of scoriaceous crust terminated abruptly against facets of lesser crust development; thirdly, those which were oriented only after a secondary fragmentation as is shown convincingly in several cases by rims of crust and patches of scoria directed away from surfaces of lesser crust development on to secondary or primary crust. A fourth class of stones which were oriented before fragmentation and re-oriented afterwards is doubtfully represented by two examples.

The various expressions of sphericity used in sedimentary petrology (Pettijohn 1957) describe with varying degrees of success, the approach to spherical shape, i.e. to minimal surface area per unit volume. None of these expressions is highly satisfactory for angular fragments of low roundness. Thus when applying the Zingg system to angular objects the manner of taking

the dimensions may require measurements between diagonally opposite corners or obliquely inclined edges. Following are the results of measuring 100 Mulga (north) stones by this method:—

Class I (tablets) ....	27
Class II (equidimensional) ..	53
Class III (prisms) ..	4
Class IV (blades) ....	16

Because the tabular specimens are partly accountable to flat "cap pieces" and to surface spalls, it is likely that the principal fragmentations yielded fragments amongst which "equidimensional" shapes considerably outnumbered the others combined. Twelve of the sixteen CP stones included in the above sample belong to Class II.

The method used to determine the sphericities recorded in column 6 of Table 2 was the ratio  $d_1/d_2$  where  $d_1$  is the diameter of the sphere of equivalent weight (calculated from weight and density), and  $d_2$  is the diameter of the circumscribing sphere. The method has the merit of simplicity but does not distinguish between the broad classes of inequidimensional shape. Further, the largest dimension is not uncommonly smaller than the diameter of the circumscribing sphere, a situation which arises also, though in the writer's experience not as frequently, in materials which have suffered some rounding by terrestrial erosion.

The sphericity values range from 0.42 to 0.88 but only 11 stones have values less than 0.5 and only a further 11 have values greater than 0.8. The mean value is 0.62. As had been anticipated, the mean sphericity value for stones of category CP is distinctly higher, being nearly 0.70.

Most of the common crust types and minor surface features have been mentioned *inter alia* above, and may now be summarised together with some rarer features. Knobby and close textured crusts predominate; scoriaceous texture is of common occurrence but very limited in area on any one stone; the striated texture is uncommon and the net texture comprising two sets of crossing striae is rare; only a single good example of porous texture was observed occurring centrally to a rim of scoriaceous crust on the rear surface of an oriented stone, an unusual location. Spattered droplets of glass occur but not in the abundance and size which constitutes warty texture, probably because of the generally small size of the stones. Surprisingly for a meteorite with a pronounced degree of recrystallization (McCall and Cleverly 1968), chondrules are not uncommonly visible in the fusion crusts as rounded and more lustrous patches—the so-called "oily stains"—and they sometimes show some detail of their internal constitution. A good example is the large (nearly 5 mm) barred chondrule visible in the primary crust of stone No. 27.

The weights of the stones (column 3 of Table 2) range from 0.2 g to 2095 g with frequency as follows:



>1000g	1
1000 to 100.1 g	31
100 to 10.1 g	253
10 to 1.1 g	442
1 to 0.2 g	54

Column 4 of Table 2 shows the weight of the stone when restored to category CP for a purpose explained in the next section. Such restorations are not possible for stones of category F, nor generally possible for any stone which does not have primary crust as the most abundant surface type, i.e. has P as the second letter in the classification. Estimates become increasingly hazardous if more than two surface types are present. In practice, estimates could be made for some of the stones of categories CPS, CPT, DPU, DPSU, DPTU, and rarely for others. Estimates were made by completing the form with modelling clay, weighing the clay and applying a factor to correct its weight to that of meteorite. When completing the shape, advantage was taken of the observation that most of the meteorite surfaces are flat or convex; when concave, they are usually only gently so. The weight of restored material was generally less than 10% of the weight of any individual and is collectively only 3% of the weight of all restored stones.

#### Fragmentation

If the pieces of Mulga (north) of mean weight 25 g were derived from a single mass of more than 19.5 kg, aerial fragmentation was clearly a highly effective process. However, for the Holbrook shower (Foote 1912; Nininger and Nininger 1950) the mean weight of the known fragments is less than 14 g though the total weight is 235 kilograms. From the mathematical estimates of the number of fragments and total mass of the Pultusk shower (Lang and Kowalski 1971) the mean fragment weight would be about 11 g for an estimated mass of two metric tons (the known material has only about one tenth of that weight).

Mean weights, at best, are an inadequate basis for comparison and there are also enormous differences in the efficiencies of collection of these showers. Foote (op.cit.) employed more than 100 people for two months in collecting Holbrook and he was followed after an interval of some years by the highly organized parties of Dr. Nininger, who made several visits; scarcely 1% of that time has been spent upon collecting Mulga (north), though the dimensions of the two strewnfields (and also that of Pultusk) are of the same order of size (Krinov 1960). The degree of fragmentation of Mulga (north) may therefore appear to have been considerably exceeded in other showers but an intensive collecting campaign might well lead to a reassessment. At least until a change in seasonal conditions brings itinerant workers to the Billygoat Donga area, the site of Mulga (north) is almost inviolable.

Amongst "finds" of meteorite showers, only Plainview is superior to Mulga (north) both numerically and in total mass, but the Plainview stones are of a distinctly larger order of size.

A consideration of the fusion crust types on Mulga (north) stones shows that series of fragmentation events were necessary for the reduction of the material to such a small average size. Individual stones weighing only one or two tens of grams may show on different facets the whole series of surface types (P, S, T, U), and the tertiary crusts may show distinctly different developmental stages on facets of the one stone. Stones which have been re-assembled from separated pieces warrant description in some detail because they are informative both as to the reduction process and the field distribution.

Pieces Nos. 3 and 199 (for details see Table 2) were found more than 300 m apart (Fig. 4). They fit together on uncrusted surface and the composite stone has classification CPS. No. 65 fits approximately upon the secondary surface (a close fit is not to be expected when opposing surfaces have each attained the rippled secondary stage of development). The fully re-assembled stone has classification CP. It appears therefore that following the initial fragmentation, a piece which weighed rather more than 150 g and which was developing primary crust, lost one end. The surfaces thus exposed ultimately developed secondary crust. At a distinctly later stage of flight, the larger piece broke across.

The pieces Nos. 149 and 176 fit together on uncrusted or thinly tertiary-crust surfaces (Fig. 3 H, J). The composite stone has primary crust at both ends, but large scars with secondary and tertiary crusts transgress the line of join. The original fragmentation thus yielded a mass which acquired primary crust and this was followed on at least two separate occasions by losses of flat slabs from the sides; finally the remnant broke across. The composite 208/209 (Fig. 3K-M) has a similar but more complex history, having primary crust at the ends with secondary and tertiary crusts of various developmental stages in a central girdle representing losses at various stages prior to the final breakage.

Specimen No. 390 fits No. 469 on part of the tertiary surface (Fig. 3G). The composite has classification DPTU, the weight as CP can be estimated reliably, and the history reconstructed. A tabular stone weighing about 14 g first lost a corner piece weighing about 1.8 g (not recovered); the scar has well developed tertiary crust (T<sub>1</sub>). Distinctly later, the main piece broke across and the edges of the break show creep of crust over the edge of the fracture surface (T<sub>2</sub>). No. 469 is one of the two pieces, but the other piece broke again and its larger fragment is No. 390; the smaller fragment of weight ca. 1.7 g was not recovered.

Specimen No. 533 has a shallow scar on one face on which No. 135 fits perfectly to form a low bulge above the surface and to make an almost complete stone. Complementary parts of the contacting surfaces show strong shearing. Possibly as a result of surface heating the up-standing portion burst out of the surface of the parent mass which was subsequently found more than one kilometre to the east of it (Fig. 4).

For simplicity in the above accounts, the development of primary or other crusts has been recounted as if each was a distinct episode; in fact, the further development of the primary crust continued simultaneously with the development of secondary and tertiary crusts on more newly exposed surfaces.

It is remarkable that pieces as light as 14 g should break and break yet again. Loss of "spalls" from the surfaces was also an important mechanism contributing to the break-down. Stones as light as 2 g show circular or ovoid scars of a few millimetres dimensions resulting from such losses. Often the losses are no more than small patches of crust. The scars are commonly partially healed by tertiary crusts. The weight of material necessary for the restoration of such scars is often insufficient to affect the weight of the stone to the nearest 0.1 g (e.g. No. 822).

Metallurgical studies of comminution include experimental investigations of the influence of the impact velocity and other variables upon such features as the reduction ratio, fragment shapes, and size distribution of the products. It would be of interest to examine the Mulga (north) material in the light of such experimental results, but comparisons are hindered by the complexities and uncertainties of meteorite fragmentation processes. The writer subscribes to the general concept that a meteorite entering the atmosphere at cosmic velocity builds up in front of it a shock wave of heated and increasingly compressed air, and that with a sufficient velocity maintained to a sufficiently low altitude (i.e. air density) the meteorite shatters itself against this self-generated barrier. The calculations of Levin (quoted by Krinov 1960 p. 75) suggest that the air pressures generated could attain the static crushing strength of common rocks. Some writers have given prominence to heat stresses, but in view of the demonstrably shallow penetration of heat effects, fragmentation from this cause is likely to be confined to the loss of thin flakes and perhaps occasionally to a more complete fragmentation triggered by such losses. These general concepts apply to oriented stones (and conceivably also to a stone which happened to be rotating about an axis parallel to the line of flight), but such stones are a minority. In the more general case of stones rotating about any other axis or tumbling irregularly, the form of the shock wave and the direction of compression relative to the stone

are continually changing. The situation of the meteorite may be compared with that of a ball compressed between a board and a table top, and forced to roll by movements of the board, movements which need not be constant either in speed or direction. Krinov (op.cit.) has drawn attention to the importance in the fragmentation process of these sharp variations in pressure on different parts of the meteorite.

The experimental work of Charles (1956) may be taken as an example of the difficulty of applying experimental results to a meteorite. Charles showed that for brittle material, equiaxial fragment shapes were favoured by high impact velocity. However, even the "low" velocity of his experiments involved impact times of only a few milliseconds. If the shattering of a meteorite involves the slow building up of pressure over a period of seconds or tens of seconds this is an exceedingly "low" velocity in the sense of the experiment. On the other hand, if a meteorite is tumbling rapidly, it might well be that even the "high" velocity conditions with exceedingly short impact times are encountered by a meteorite during atmospheric flight.

Not the least of the advantages of the controlled experiment is that the test piece may be shattered by a single blow and the fragments examined. They frequently contain secondary i.e. internal, non-bounding fractures. A meteorite fragment containing secondary fractures will presumably have a much reduced crushing strength and be especially liable to further failure, perhaps only momentarily later when it adopts a suitable orientation. When fragmentations are separated by very short time intervals, it is not possible to distinguish between the products of the two events. Thus the application to meteorites of even the well established relationships of size distribution of products is also complicated by uncertainties.

The method and nomenclature of Frost (1969) will be followed in the treatment of size distribution. A Gaudin population of sizes resulting from high speed impact is described by the relation

$$y = 100 (x/K)^m$$

where  $y$  is the cumulative weight percent finer than size  $x$ , and  $K$  and  $m$  are constants for any one population. For distributions of this type, the graph of  $\log y$  against  $\log x$  or against  $x$  expressed in phi units (i.e.  $-\log_{10} d$ , where  $d$  is diameter in mm) will be a straight line with  $K$

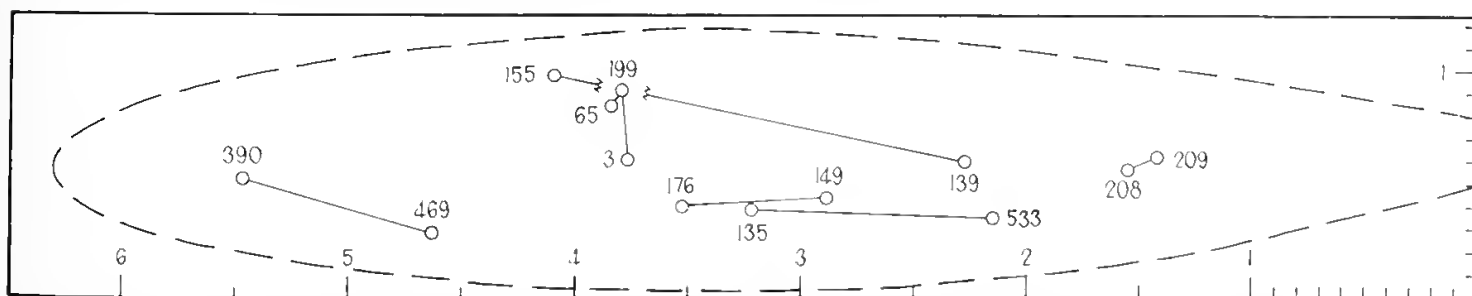


Figure 4.—Distribution of some fitting fragments (linked by lines) of the Mulga (north) meteorite, constituting partial minor distributions within the general stewnfield. Numbers along the lower and right-hand edges are kilometres west and north respectively of datum.

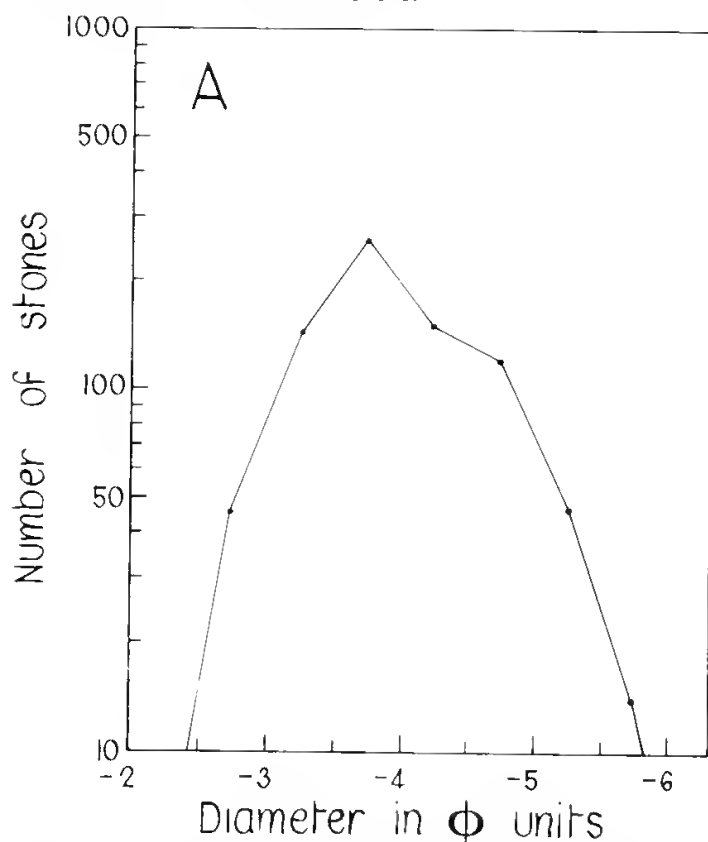
the maximum size and  $m$  a measure of the slope or sorting. Size is conveniently expressed in terms of an equivalent sphere. It may be deduced from the Gaudin equation that

$$d = -3.024 - 1.1073 \log_{10} M$$

where  $d$  is the diameter of an equivalent sphere in  $\phi$  units and  $M$  is the mass of the stone in grams; the constant embodies the special case of the Mulga (north) shower, for which a density of  $3.6 \text{ g/cm}^3$  has been used. Badly weathered material on the one hand and the freshest material on the other might differ by as much as  $0.1 \text{ g/cm}^3$  from the adopted mean density figure, but the result is generally affected by only about  $\pm 0.01 \phi$  unit.

Frost (op.cit.) has concluded that a first estimate of 0.5 for  $m$  for both meteoritic stones and irons is not unreasonable, and the value 0.5 will be used here in order that results are on a comparable basis. In fact, an estimate of  $m$  for Mulga (north) gives a somewhat lower value, though it is well within the range found by experiment.

Figure 5A is a simple frequency diagram for the numbers of stones of Mulga (north) falling within intervals of half a  $\phi$  unit. Disregarding stones smaller than  $-3\frac{1}{2} \phi$  units (of weight less than 2.7g) and those larger than  $-6 \phi$  units (weight greater than 500 g), both of which groups are probably inadequately collected, there remain five points of reasonable reliability on the diagram. The line of best fit for these points applied to the Gaudin distribution leads to an estimate for  $m$  of about 0.4.



Cumulative size distribution curves are shown in Fig. 5B. Curve No. 1, which was prepared when only 405 stones were known, has a steepness comparable with the curves figured by Dr. Frost, but with a greater regularity than most of them arising from the large numerical size of the sample. Assuming that  $m$  has a value of 0.5 and that departure of the curve from the straight line representing Gaudin distribution is related solely to non-recovery of fine material the non-recovery of Gaudin-distributed small stones may be calculated. From the ten percent ordinate, the non-recovery is  $(54-10)/100/(100-10)$ , or about 49%.

Curve 2 of Fig. 5B represents the 781 pieces presently known, and shows the distinct improvement resulting from the additional collecting. The upper portion approaches the Gaudin distribution with slope 0.5 as shown by the straight line; the non-recovery figure on the same basis is only 34%. Considering that only the 13 largest stones of Mulga (north) attain the size of the smallest material graphed by Dr. Frost for showers such as Tenham, these results appear highly gratifying, but the comparison is not strictly valid. It is noted that the material of those showers generally showed only one or two of the surface types designated in this paper by P, S, T and U, and therefore they were not the products of a series of fragmentation events.

It would afford a more valid basis for comparison if the products of a single fragmentation of Mulga (north) could be singled out. This has

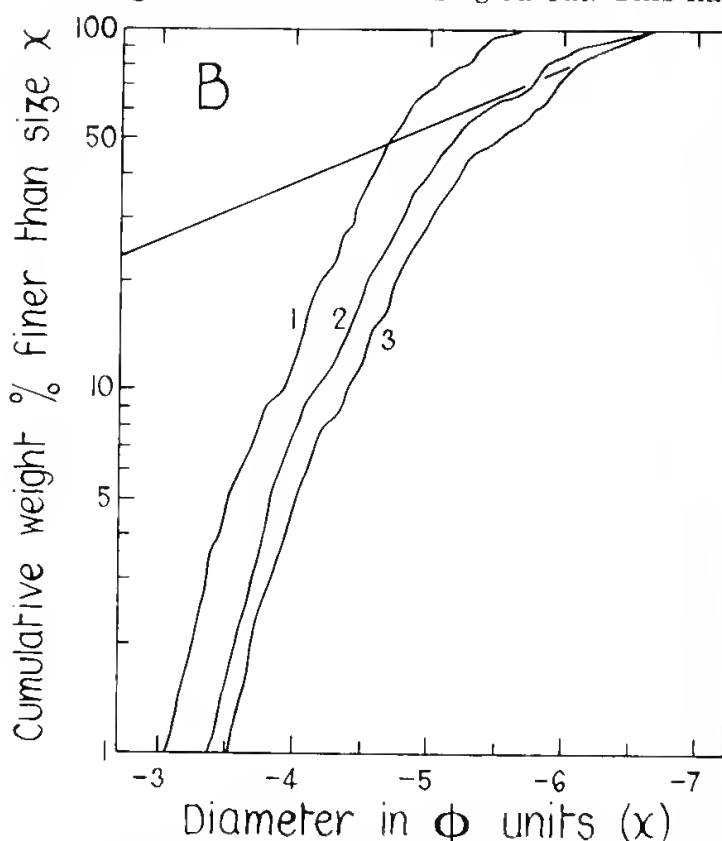


Figure 5.—A.—Simple frequency diagram for pieces of the Mulga (north) meteorite shower in  $\phi/2$  ( $\frac{1}{2}$   $\phi$ -unit) intervals. B.—Cumulative curves of size distribution for the Mulga (north) meteorite. No. 1.—for the 405 pieces known to December, 1970 (for clarity, this curve has been displaced 0.4  $\phi$ -unit to the left of its correct position); No. 2.—for all 781 pieces known to December, 1971; No. 3.—for pieces resulting from the initial fragmentation. The straight line is the Gaudin distribution of slope 0.5 positioned appropriately to curve No.2.

been attempted for the initial fragmentation, but rather sweeping assumptions are necessary—viz. that a single stone entered the earth's atmosphere, that the products of its initial fragmentation were capable of developing fully a primary crust, and that the products of later fragmentations were incapable of developing such crust on the newly exposed surfaces. Stones which would then qualify for inclusion in the sample are:—

1. Stones classed as CP.
2. Stones which can be restored to class CP, using diameters equivalent to the restored condition.
3. A few oriented stones of category CPS or similar, for which the surface of lesser crust development has been accepted as the result of sheltered location rather than of late exposure. Such stones may be identified in Table 2 by the weights and restored weights being identical.
4. Composite stones formed by uniting pieces found separated in the strewn-field, with or without restoration. Only three examples, one of which has a marginally acceptable degree of restoration, qualify for inclusion in this group.

Consideration was given to inclusion in the sample of small stones of inequidimensional shape of categories such as CPS. The doubt was that light stones of such shapes could maintain a sufficient velocity to develop fully a primary crust. However, the tabular pieces which are the majority of the group, might be only surface spalls from larger stones and the decision to exclude this small group cannot affect the cumulative weight curve significantly.

The acceptable groups comprise only 41% of the stones but nearly 60% of the mass, of which 1% is restored material. Twenty of the thirty heaviest stones belong to one or other of the first two groups. The mean weight of stones in the sample is 36 g compared with a mean weight for all stones of 25 grams.

Curve 3 of Fig. 5B thus purports to represent a sample of the products of a single fragmentation event. It is slightly steeper than curve 2 which represents all stones. The non-recovery figure on the same basis is 38% as against 34%. This slightly greater steepness is in accord with experimental experience (Gaudin and Hukki 1944), but the major problems of recovery of material and isolation of the sample from other products do not arise under controlled experimental conditions. Curve 3 is rather flatter than those figured by Frost (1969 Fig. 2), with which, if the exercise had been successful, a comparison would now be valid, but there is good reason to believe that it is not. For the sample to be fully satisfactory, it is desirable that only the largest products of the initial fragmentation should have been removed by secondary and later fragmentations. The removal of only the largest products from a Gaudin-distributed population of sizes does not affect the slope of the

line but simply displaces it towards the smaller sizes. Clearly, the reassembled stones considered above range down to quite small size and none of them even approaches the size of the largest stone recovered. A portion of the sample with unknown size distribution has therefore been removed by the later events. The difficulty might be resolved by completely reassembling all broken material, but despite repeated trials, the reassembled stones constitute but an insignificant fraction of it. Though the isolation of a sample of products of the initial fragmentation might have been successful, it cannot be claimed that the sample is thoroughly satisfactory for use in this way.

The curves 1 to 3 of Fig. 5B were commenced from the relatively low 1% level because of the large number of small pieces known. Curve 2 is not greatly steeper in the 0.1%-1.0% range than in the 1%-10% range (it requires 36 stones to attain the 0.1% level). It is likely that the lower portions of these curves would not be significantly flattened by further collecting because there is no real difference between the lower parts of curves 1 and 2. There would be difficulty in detecting smaller material, particularly when it might be widely dispersed by atmospheric winds and weathered. It would be doubtfully advantageous to collect in the more genial winter season because past experience has been that the area is usually densely covered by tufted grasses of knee height or higher.

#### *Field Distribution*

Only qualitative and semi-quantitative observations are offered.

A simple conception of an elliptical strewn-field is that fragmentation during oblique approach results in an expanding cone of pieces which therefore meet the earth's surface in an elliptical area. The combined effects of gravity and air resistance, invariably present, result in some grading in the direction of flight, heavier fragments in general travelling further whilst light ones are more readily drawn into the vertical with free fall velocities. Other factors such as atmospheric winds also affect the distribution. Shape factors can be expected to have an influence, including the degree to which winds can affect the distribution. Of particular interest in the case of Mulga (north) are the effects of multiple fragmentation events. These later events at somewhat lower levels and steeper angles of approach can be expected to yield smaller and more equidimensional ellipses with less evident grading in the forward direction. Finally, when fragmentation occurs during vertically downward flight, dispersal may be expected over a circular area with grading (if any) a function of distance radially outward, and hence just as effective in the backward as in the forward direction.

Depending upon factors which could influence the altitude, timing and energy expended in fragmentation events, the individual areas of dispersal could be completely or only partially superimposed on others, or could occur quite independently at a distance. It seems likely that

with sufficient data a general mathematical expression could be found to describe the distribution in the case of a single event, but for a shower such as Mulga (north), the distribution would involve the integrated result of a whole family of such expressions.

It is not possible to illustrate diagrammatically the full details of distribution of Mulga (north) because of the combination of an overall dimension exceeding 6000 m with interfragmental distances ranging down to less than one metre. Referring to the weight categories of Fig. 6 in descending order, 14 stones of the third category and 44 stones of the fourth category have been omitted from the figure (mostly from the western end); all 55 stones of weights 0.2–1.0 g have been omitted. The general increase in fragment weight to the east is evident in the diagram but is not as marked as might be expected for a relatively narrow ellipse. Multiple fragmentation and the loss of flakes from the surfaces are regarded as the two factors principally responsible for the large overlaps of the weight categories.

The distribution of the component parts of one of the re-assembled stones shows that heavier fragments are not necessarily found further along the line of flight. The composite stone 155/139/140 can be restored to class CP with reasonable confidence. No. 155 weighs more than 150 grams. The balance of the original stone could not have weighed more than 90 g, i.e. if all of the missing material was incorporated with Nos. 139 and 140, and this fell more than 1.8 km further east. The generally tabular shape of No. 155 might provide a partial explanation, but it seems likely that for the later fragmentation events as distinct from earlier ones in more nearly horizontal flight, the fortuitous directions of scatter from the point of burst may have a decisive influence on the points of fall. Note:—Stone No. 140 was belatedly recognised as an impact fragment of No. 139 and so also most likely is No. 141, though it cannot be fitted.

If the distribution of the oriented stones is to be used as an indication of the flight path, the ones most likely to be reliable are the 30 of category CP and 12 of other categories as follows:—CPT Nos. 69, 245, 341, 355, 370, 624, 634, 658, 815; CPS Nos. 260, 759; CPST No. 309. These 12 oriented stones require insignificant amounts of restoration, or in a few cases, have surfaces of lesser crust development attributable to sheltered location. This sample totalling 42 stones is rather inadequate for mathematical treatment, but from visual inspection of a plot of the sites there appeared no reason to change present concepts of the position of the axis of the distribution or the essentially west to east direction of flight. Indeed, for such a small number of stones, the plot has a surprising degree of resemblance to the general distribution.

The general trends of the lateral distribution were determined by dividing the strewnfield into transverse strips 1 km wide, each strip overlapping its neighbours by 0.9 km, and plotting the

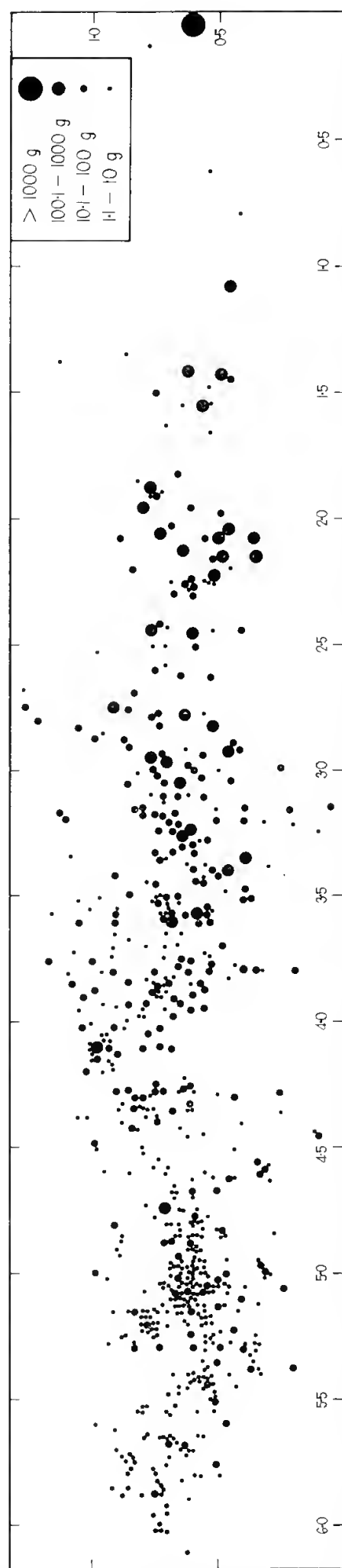


Figure 6.—Diagrammatic representation of the distribution of about 85% of the known pieces of Mulga (north) meteorite (for omissions, see text). Marginal figures along length and width of diagram are kilometres west and north respectively of the datum.



numbers of stones or other statistics at abscissae representing the mid-lines of each strip. The number of stones in each strip is a maximum near the western end of the strewnfield and declines rapidly eastward but with a distinct reversal and secondary maximum at 3.9 km W, where dense crowding may be seen in Fig. 6; the curve has the same general shape if stones/km<sup>2</sup> are plotted but the secondary maximum is less prominent. The weight of material in transverse strips is minimal near the western end and increases eastward, but with a marked inflection centred on about 4.8 km W to attain a maximum at 3.4 km W, and thereafter decreases rapidly; again, the asymmetry is retained on a weight/km<sup>2</sup> basis.

The mean weight of stones in transverse strips is minimal at the western end and increases steadily eastward. It is valid in this case to consider the CP stones separately on the same basis because the removal of some stones—not necessarily the largest—by further fragmentation does not affect the points of fall of other individuals. Stones requiring insignificant restoration may also be included in the sample but all others must be excluded because as complete individuals they would almost certainly have landed elsewhere. The resulting curves

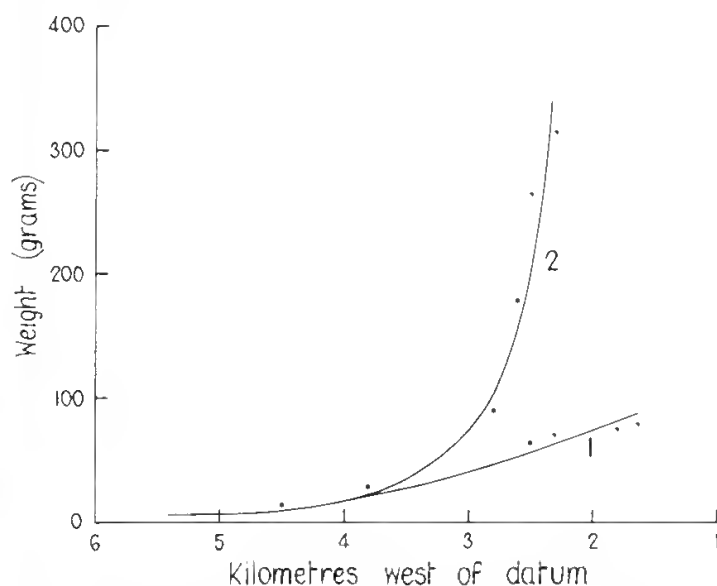


Figure 7.—Mean weights of stones of the Mulga (north) meteorite found in N-S strips 1 km wide, each strip overlapping the neighbouring strips 0.9 kilometre. Curve 1.—All stones; Curve 2.—Completely primary-crusted stones. Only points not falling closely on the curves are shown in the figure.

(Fig. 7) show clearly that there is a real difference between CP stones and the general sample. The curve for CP stones suggests some form of logarithmic relationship between mass and distance, but too much cannot be read into curves of means plotted at mid points. For the same reason, the complexities of the other curves cannot be interpreted as indicating two populations, though that might well be true.

Some limited trials were made with scatter diagrams for individual stones and the best of these appeared to be that of log weight against distance when confined to CP stones (c.f. Frost

op.cit.p.228), the "sorting factor" being from inspection of the order of 1.5. The detailed treatment of the distribution has, however, been left to the mathematical specialist.

### Acknowledgments

I thank M. K. Quartermaine and T. G. Bateman whose energetic and voluntary search efforts were responsible for more than three quarters of the meteorite finds. I am especially grateful that they returned again to the area with me in 1971 whilst aware of the climatic conditions to be expected and of the severe limitations on water usage.

W.A. School of Mines vehicles were freely used on field work, the three earlier visits being made while the School was a branch of the Mines Department of Western Australia, the two most recent visits since the School became a branch of the Western Australian Institute of Technology.

### Appendix

Weights, sites of find, and distribution in collections of the meteorites are given below. Some of the earlier recoveries made by School of Mines personnel have been either donated to or exchanged with the Western Australian Museum, and the later recoveries have been handed over in accordance with the Western Australian Museum Act of 1969 whereby the meteorites are Crown property and are vested in the Museum.

**Mulga (south).** See Table 3. The second and sixth items of the table are in the W.A. School of Mines collection, the balance in that of the Western Australian Museum.

Table 3

Weight and locality details of Mulga (south) meteorite

Year of find	W.A.S.M. Catalogue No. or field No. (brackets)	Weight g	Westing km	Northing or Southing (S) km
1963	9584.1	59.5	ca.4.9	ca.0.7 S
"	9584.2	52.6	ca.4.9	ca.0.7 S
"	9584.3	16.2	ca.4.9	ca.0.7 S
1964	9738	76.2	ca.4.0	ca.0.55
"	9739	26.0	ca.4.0	ca.0.55
"	9740	28.5	ca.3.9	ca.0.1 S
"	9741	18.9	ca.4.5	ca.0.8 S
"	9742	20.2	ca.4.5	ca.0.8 S
1970	(110)	65.5	2.87	0.86
"	(179)	112.0	3.94	0.59
"	(323)	27.9	4.02	0.50
1971	(435)	26.8	5.06	0.41
"	(449)	38.0	5.65	0.44
"	(460)	2.9	4.84	0.28
"	(468)	160.2	4.57	0.21
"	(488)	32.6	4.25	0.25
"	(506)	73.5	4.69	0.32
"	(531)	1.5	2.22	0.40
"	(532)	13.6	2.22	0.40
"	(539)	19.4	1.40	0.51
"	(558)	1.2	3.53	1.15
"	(595)	1.3	1.55	0.56
"	(667)	0.3	5.58	0.82
"	(690)	19.5	5.64	0.69



**Billygoat Donga.** See Table 4. The main portion of the original stone found by T. and P. Dimer is in the W.A. School of Mines collection (9469), the other two pieces in the Western Australian Museum collection.

**Table 4**

*Weight and locality details of the Billygoat Donga meteorite*

Year of find	W.A.S.M. Catalogue No. or field No. (bracketed)	Weight g	Westing km	Northing km
1962	9469	142	ca.3.5	ca.7
1970	(225)	392.4	4.25	0.85
1971	(493)	98.4	4.42	0.69

**Mulga (north).** Full details of the material set out in the pattern of Table 2 are available on application to the Director, Western Australian Museum, Perth, Western Australia. Ownership follows:—

Smithsonian Institution: Field Nos. 72-84.

W.A. School of Mines: Field Nos. 1-5, 7-10, 12, 14-21, 23-36, 38-43, 45, 46, 48 (part), 49-59.

Western Australian Museum: The balance of the material.

**Mulga (west).** Field No. 430, weight 169.2 g. found at 5.29 km W and 0.19 km N in 1971 is in the Western Australian Museum collection.

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